Macneill. Canal navigation.

CANAL NAVIGATION.

CANAL NAVIGATION.

ON

THE RESISTANCE OF WATER

TO THE PASSAGE OF

BOATS UPON CANALS,

AND OTHER

BODIES OF WATER,

BEING

THE RESULTS OF EXPERIMENTS,

MADE BY

JOHN MACNEILL, M.R.I.A.

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS, LONDON.

——————*"mare per medium, fluctu suspensa tumenti*
Fert iter." VIRGIL.

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LONDON:
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TO

FREDERICK PAGE, ESQ.

OF SPEEN,

CHAIRMAN OF THE COMMITTEE OF MANAGEMENT OF THE KENNET AND AVON CANAL, &c.

ONE OF THE

[illegible]

ERRATA.

Page 2, in foot note, *for* Brooker, 1727, *read* Brook, 1827.
5, line 8, *for* ten hours, *read* in hours.
8, — 11, *for* the point, *read* that point.
9, (in General Observations) *for* standard adapted, *read* standard adopted.
18, table II. in columns 2 and 3, line 6, relates to experiment No. 16, line 11 to No. 21, line 16 to No. 26, line 21 to No. 31, line 26 to No. 36, and line 31 to No. 42.
25, in line 9, from the bottom, *for* $m\left(\frac{v-v}{v}\right)=p$, *read* $m\left(\frac{V-v}{V}\right)=p$, and in the same line *for* and v. *read* and V.
28, the "time of passing each stake, &c. should have been so recorded in column 1, that the interval of time occupied in passing over the distance," &c. might have been read in the following manner:—

h.	min.	sec.	
2	53	41	38, and so on through the table.
2	54	19	

33, in line 15, *for* are very oblique, *read* is very oblique.
38, in last line of text, *for* formulæ, *read* formula.
39, in the record of Mr. Walker's experiments, on line 6 of figs. *for* 4·72, *read* 47·2; on line 7, of figs. *for* 4·95, *read* 49·5.

Your most obedient Servant,

JOHN MACNEILL.

Strand, May, 1833.

b

LONDON:
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TO

FREDERICK PAGE, ESQ.

OF SPEEN,

CHAIRMAN OF THE COMMITTEE OF MANAGEMENT OF THE KENNET AND AVON CANAL, &c.

ONE OF THE

DEPUTY LIEUTENANTS OF THE COUNTY OF BERKS.

SIR,

To you, as thoroughly acquainted with Canal Navigation, and as the strenuous supporter and defender of canal property, I beg to dedicate this pamphlet.

The personal exertion, liberal spirit, and determination, which you have shown in examining the merits of the improvements proposed in it, convince me that I could not dedicate the result of my labours to one more capable of forming a correct judgment on the important facts elucidated, or one more willing and able to make an impartial and beneficial use of them than yourself.

I am, Sir,

Your most obedient Servant,

JOHN MACNEILL.

Strand, May, 1833.

b

INTRODUCTION.

THE results which I have arrived at by experiments are so much at variance with generally received theoretical deductions, that it is with much diffidence I submit these pages to the consideration of the public, and to those more immediately concerned in Inland Navigation. The following observations are made with a hope that those discrepancies between theory and practice may tend to a more rigid adherence to experimental inquiries in other branches of practical science, but especially, that they may lead to a more varied and extensive series of experiments to ascertain the best form of boats, not only at the cost of public companies, whose canal property may well demand it, but also at the expense of government, who lay out large sums in steam navigation; for I trust it is clearly shown, that very great alterations and improvements may be made in the models of all ships and boats which are not impelled by the wind, and that passengers and light goods may be carried by canals at a velocity hitherto supposed to be impracticable.

ON THE RESISTANCE OF WATER

TO THE

PASSAGE OF BOATS UPON CANALS,

&c.

THE laws which regulate the resistance and impulse of fluids, are involved in such obscurity, that candid investigators of this branch of science, are compelled to confess, that the dissertations of the physico-mathematician have failed in utility, and that even the deductions of the logician have been almost altogether ineffectual. The assumptions of the former, from which propositions have been deduced, and theories given out, are, at best, founded only on an hypothesis; the reasonings of the latter, rest upon limited experience, and in some cases ill observed phenomena. And there is, probably, no branch of science which has so much engrossed the attention of the philosopher, and from which so little practical good has resulted.

That such is the fact, and that the farther the subject has been investigated, the more difficulties have been met with, if not always acknowledged, few can venture to deny.

If, in his zeal for information, the inquirer of the present day searches the shelves of philosophy, his labour will terminate in the settled conviction, that this branch of science is but yet in its infancy: even, although illustrated by the novel algebraical calculus, and the beautiful results derived from it by French ingenuity. A long course of patient experiment will alone warrant the adoption of formulæ; for, as yet, as far as regards the mere resistance of the fluid, the practical application of the laws founded by the mathematician, has failed in producing any form which will rival the skiff of the Indian, the canoe of the Esquimaux, or the junk of the Chinese.

These observations apply to all boats and ships impelled by any other force than the wind; and this must not be forgotten, whilst we proceed to examine one particular department, viz. Canal navigation. Every body moving in, or upon the water, it will be seen, is under similar laws; and although the following results apply particularly to canal boats, they nevertheless are applicable to every other body which has to make its course by water.

The object immediately in view, when we place a boat or barge upon water, is a good conveyance for persons and property. So is it when we place a wheeled carriage upon a gravelled road, or a sledge upon snow. The difference, however, in the modes of attaining this object, has been most striking. In each of these cases, the body to be moved, has been rested on soft or yielding matter, and whilst, in the two latter cases, no mechanician would provide for the wheels of the carriage, or the runners of the sledge, a facility for cutting along, immersed in the softer matter under them, the boat builder seems to have studied how he could best keep his vessel ploughing her way. The case may be different with sea-going vessels, which are impelled by the action of a wind "on the beam," and ships of war, with their decks loaded with weighty guns: in such cases it is necessary that the vessel be a good deal immersed. Nor can it be satisfactorily shown that even sea-going ships would not be improved by such a build as would enable them to rise to the surface of the water. But, to pursue our *reductio ad absurdum;* there are many cases in navigation where a sharp "cut-water" shape to a boat, would be as unphilosophical as a knife-edged felloe would be to a wheel intended for ploughed land. A cart-wheel will, on gravel or other yielding matter, sink to the determined line of gravitation with as much certainty as will a boat upon water; and a boat resting in water will (according to the velocity given to it, and the form of its prow and bottom) rise nearer the surface of the water, as well as a cart-wheel will rise, when put rapidly into motion. The difference of density is, no doubt, much greater in one case than in the other; but the water will resist the penetration of the boat in the same manner, though not in the same degree, as the soft gravel, or mould, resists the wheel. Notwithstanding a conclusion so obvious to those who know the laws of gravitation and the properties of matter—so easily calculated by every one who understands any thing of the combination of forces;* we find it has been neglected, in order to determine what law regulates the movement of a body immersed to the same depth, at all velocities.

At a time when it was generally held, that the resistance to a vessel in the water increased in the duplicate ratio of the velocity of the vessel through the water, the now keenly contested merits of rail-way transport, and canal transport, were brought under public discussion. Experiments were instituted in order to

* We find a good illustration of this resistance in "A Winter in Lapland and Sweden, by Arthur de Capell Brooker, 1727," p. 338.—"The real superiority of the skielöbere is chiefly shown when the enemy halt after a long march. Whatever precaution may then be taken, they are in constant danger from troops which have no occasion for path or road, and traverse with indifference marshes, lakes, rivers, and mountains. Even in those parts, where the ice is too feeble to bear the weight of a man, the skielöbere glides safely over by the mere rapidity of his motion.

confirm this law of resistance, but it occurred to none of the experimentalists that, although they could not increase the density of the water, or harden it, as has been done with roads for carriages, that they could still increase the relative resistance of water, by giving the boat such velocity that her prow could not penetrate fast enough, and thus that she should rise out of the fluid. They might have reasoned, by a perfectly fair analogy between conveyance on land or on snow, and conveyance on water, and have legitimately concluded that, as their object was not to cut through gravel, but to get on it, in the one case, so at high velocities in the other, they should not have endeavoured only to cut through the water, but also to raise the boat to the surface, and make her skim thereon.

Such facts are obvious to all, who have seen a boy make a thin stone skim the surface of a lake,—who have watched the action of a cannon ball on the smooth sea,—who have felt the difficulty of making any impression upon the stream forced from the small apperture of a fire-engine hose-pipe,—or, indeed, who know any thing of the properties of matter; but they had never been applied to the purposes of navigation, until it occurred to Mr. Houston, of Johnstone Castle, to try the effect of a light gig-shaped boat upon a canal; and it is very surprising that the most strenuous advocates for the adoption of such boats, still reject the above facts, as irrelevant. It matters not whether the water be forced against the object, or the object be forced against the water.

In the month of June, 1830, Mr. Houston succeeded in having a light, long, and shallow wrought-iron canal boat, established upon the Ardrossan canal, in Scotland, between Paisley and Glasgow. Since that period, such boats have continued to run regularly, conveying about sixty passengers a distance of "twelve miles, at a rate of eight miles an hour, stoppages included." Succeeding improvements in the construction of the boat, as well as in the mode of working the horses, enable us to state the above as a minimum of performance. In the Appendix (A) will be found a specification of one of such boats, and Plates III. IV. and V. show their form and dimensions. The following quotation from the advertisements, the truth of which is well authenticated, shews the cheap rate of conveyance.

		Distance.	Cabin.	Steerage.
"Fare between	Glasgow and Paisley . .	8 miles.	9*d*.	6*d*.
Ditto	Glasgow and Johnstone . .	12	12	9
Ditto	Paisley and Johnstone . .	4	5	3

Intermediate distance as in the way-bill.

"The boats, at times, carry twelve hundred passengers in one day; and during eight months of last year, (1832,) notwithstanding the prevalence of cholera, they conveyed one hundred and twenty-six thousand passengers, which is at the rate of fifteen thousand seven hundred and fifty, monthly."

Mr. Thomas Grahame, in his "Letter to Canal Proprietors and Traders," says "The experiments of great velocity have been tried and proved *on the narrowest, shallowest, and most curved Canal in Scotland,* viz. the Ardrossan or Paisley Canal, connecting the city of Glasgow with the town of Paisley and village of Johnstone, a distance of twelve miles." The result has disproved every previous theory as to difficulty and expense of attaining great velocity on canals; and as to the danger or damage to the banks of canals by great velocity in moving vessels along them.

"The *ordinary speed* for the conveyance of passengers on the Ardrossan canal, has for nearly two years been *from nine to ten miles an hour,* and *although there are fourteen journies along the canal per day, at this rapid speed, the banks of the canal have sustained no injury.* * * * * * The boats are formed seventy feet in length, about five feet six inches broad, and, but for the extreme narrowness of the canal, might be made broader. They carry easily from seventy to eighty passengers, and when required, can, and have carried, upwards of one hundred and ten passengers. The entire cost of a boat, and fittings up, is about £125. The hulls are formed of light iron plates and ribs, and the covering is of wood and light oiled cloth. They are more airy, light, and comfortable than any coach. They permit the passengers to move about from the outer to the inner cabin, and the fares per mile are *one penny* in the *first,* and *three farthings* in the *second cabin.* The *passengers are all carried under cover,* having the privilege also of an uncovered space. These boats are drawn by two horses (the prices of which may be from £50 to £60 per pair) in stages of four miles in length, which are done in from twenty-two to twenty-five minutes, including stoppages to let out and take in passengers, each set of horses doing three or four stages alternately each day. In fact, the boats are drawn through this narrow and shallow canal, at a velocity which many celebrated engineers *had demonstrated, and which the public believed, to be impossible.*"

Mr. Grahame then proceeds making apparent his want of confidence in railways—"The entire amount of the whole expenses of attendants and horses, and of running one of these boats four trips of twelve miles each (the length of the canal) or forty-eight miles daily, including interest on the capital, and twenty per cent. laid aside annually for replacement of the boats, or loss on the capital therein invested, and a considerable sum laid aside for accidents and replacement of the horses, is £700 some odd shillings, or taking the number of working days to be three hundred and twelve annually, something under £2. 4*s.* 3*d.* per day, or about eleven-pence per mile. The actual cost of carrying from eighty to one hundred persons, a distance of thirty miles (the length of the Liverpool railway) at a velocity of nearly ten miles an hour, on the Paisley Canal, one of the most curved, narrow, and shallow canals in Britain, is therefore just £1. 7*s.* 6*d.* sterling.

Such are the facts, and incredible as they may appear, they are facts which no one who enquires can possibly doubt."

The following is a statement I am enabled to publish, showing the gross expense of running old heavy boats on the Paisley canal at the rate of four miles per hour, and new light boats, on the same canal, at the rate of ten miles per hour, and the comparative expense per mile; also the number of passengers carried before and after the introduction of the high and cheap speeds.

	1830.*	1831.†	1832.†
Speed ten hours, . . miles	4	10	10
Number of passengers carried . .	32831	79455	148516
Number of miles run each day . .	48	varying	152
Gross expense in year . . .	700. 4*s*. 7*d*.	1316*l*. 17*s*. 5*d*.	218*l*. 5*s*. 11*d*.
Cost per mile, year taken at 312 days .	11*d*.	——	10¾*d*.

* These charges are the bare outlays.

† These charges include loss on purchase and sale of additional horses, and ten per cent on cost of horses, boats; deposited in a contingent fund.

The power of conveyance, thus established on the Paisley Canal, may be judged of from the fact, that on the 31st of December, 1832, and 31st January, 1833, there were conveyed in these boats nearly two thousand five hundred passengers.

The number of passengers continue to increase. The number carried in April, 1833 was twenty thousand, or at the rate of two hundred and forty thousand yearly.

It does, therefore, appear surprising, that Canal owners in particular, whose property was daily becoming less valuable in the share market, by the alleged superiority of rail-way conveyances, should have been so blind or supine as to allow nearly three years to pass over, without making vigorous efforts to follow the successful example; but it is not the less true that they were, and indeed are still, so—although, if the system be a good one, and practicable, and lucrative, as to me it appears undoubtedly to be, they could not have hit upon a more happy arrangement for keeping up their dividends, and for improving their property to a greater extent than it has arrived at, since the commencement of canal navigation in England. In many situations throughout the kingdom, where the quick transit of passengers, and even of light goods, was of consequence, it would not only enable the canal companies to compete with existing turnpike roads, but also to supersede the necessity for rail-ways for general purposes.

We must suppose that canal proprietors did not credit the various reports in circulation as to the speed at which the boats were drawn upon the Paisley canal; the ease with which horses performed their work; and the small surge produced on the sides of the canal. But even supposing, many of these reports to be exaggerated, and that false conclusions were come to by those who witnessed the performance, the great points of speed and economy were established to the satisfaction of many inquirers. Had the facts been known to canal proprietors, we should have expected the institution of a series of experiments, long ere this, for ascertaining the actual resistance of boats at high velocities and under every variety of circumstance, as well as the best form of boat suited to these velocities; the height of the wave or surge, as well as its character and effects; and many other important features which were now for the first time exhibited.

It is most unaccountable why canal companies did nothing to determine such; and it is to be hoped they may now be induced to institute extensive experiments. The few experiments which are detailed in the following pages, though made with as much accuracy as circumstances would admit, and though they are conclusive on some points, are by no means as extensive and varied as the importance of the subject demands. The scale of expenses was so exceedingly limited that they could not be carried farther, and others of still greater importance have not, in consequence, been undertaken, and remain yet to be made.

The energy and inquiring habits of Mr. Telford would not let such a practically useful inquiry, remain dormant. He therefore directed me to make some preliminary experiments upon a small scale, and to his liberality we are indebted for the first series, which were made entirely at his expense, in the National Gallery of Practical Science in Adelaide Street; where the arrangements of the room were so admirable, and the accommodation, which the managers of the Gallery always gave for uninterrupted experiment during three weeks, was such,* that the most accurate results were obtained on a limited sheet of water.

Plate (I.) represents the plan and elevation of the reservoir of water in the National Gallery of Practical Science in Adelaide Street, with the apparatus which was fitted up by Mr. Saxton for the purpose of making the experiments. The straight part of the reservoir is seventy feet long, and four feet wide, with upright sides. The wheel and axle, B & *b*, were of excellent workmanship; the

* Every gentleman who witnessed the experiments, and saw the facilities with which the Committee and their manager, Mr. Payne, gave, agrees with me in bearing testimony to the liberal and philosophical spirit with which we were aided. They not only allowed a large portion of the Gallery to be set apart, and put themselves to considerable inconvenience, but ordered the free admission of all persons interested or assisting in the experiments.

axle, on which the weight acted, was of hard wood, three and a half inches in diameter, and the wheel on which the line that pulled the boats was coiled, was of brass, thirteen inches in diameter; the axis on which the wheel and axle turned was of polished steel, half an inch in diameter, working in brass. The pulley or sheeve F, *f*, which was attached to the tin box or can, C & *c*, which held the weights, was of brass, two and a half inches in diameter, and its axis was of steel, with conical points working in brass. The line used for the weight was of cat-gut, one-eighth of an inch in diameter, and the lines used for pulling the boats were in some of the experiments of silk, in others hemp, varying in thickness from one-fortieth to one-twentieth of an inch in diameter. The tension of the line in each experiment, or the force, which was exerted on the boat by a given weight, placed in the bucket C & *c*, was not determined by calculations, but practically and accurately ascertained, not only by a spring dial placed on the line, as at *f*, but also by an accurate beam and scales, furnished by Mr. Simms; by which means any mistake or inaccuracy in estimating the quantity of power, was effectually prevented. The boat is seen at (*a*, *a*,) as she appeared in her passage from one end of the straight canal to the other; the moving power being the weight in the bucket (C & *c*.)

In making some preparatory experiments it was found that a considerable space was necessary to be passed over by the boats, from the point of starting, before they acquired a uniform velocity. It was, therefore, found necessary to limit the distance, over which the uniform motion was measured, to a space of fifty feet, and consequently, great accuracy was necessary in determining the time of the boat's transit over so short a space. I therefore applied to my friends, Messrs. Arnold and Dent, the celebrated chronometer makers, in the Strand, who, with that liberality which usually accompanies science, not only furnished me with chronometers, but Mr. Dent himself more than once assisted in measuring the time, and comparing it with that observed by Mr. Turnbull and Mr. Bourns, whose accurate and careful observations have contributed so much to the success of these experiments.

Occasionally two, and sometimes three chronometers were used, placed, as at (*h*, *h*,) on brackets, screwed to the side of the reservoir, at the commencement, and at the end of the measured space.

Close to these chronometers, and exactly at fifty feet apart,* two brass wires were stretched across the reservoir, at eight inches above the surface of the water; by means of which wires, the observers could determine the exact instant of time

* In most of these experiments this distance was reduced to thirty feet, as shewn on the "general plan."

that the bow of the boat came under them, as they were slightly touched by a slender piece of brass wire rising perpendicularly from the stem of the boat.

In some of the first experiments it was found extremely troublesome to ascertain the exact interval of time of the boats passing between the wires, in consequence of the chronometers having different rates of going; but, this difficulty was obviated by a suggestion of Mr. Cubitt, who proposed that, after a certain number of experiments, the place of the chronometers should be changed, and the experiments repeated. This effectually obviated the difficulty, and enabled us to get the time with great precision. In the latter experiments, only one chronometer was used; it was placed on the bracket at the first wire, and a line was brought from the second wire, along the side of the reservoir, up to the point: by which means the observer, holding the line in his hand, and keeping his finger on the wire next him, was enabled to ascertain by the touch, the passage of the boat under each wire, and the exact time intervening between each wire, by counting the number of beats of the chronometer. These experiments were frequently repeated, and the times noted by different observers, without communicating the results to each other until each series was completed, after which they were compared, and the mean time taken.

In making the experiments, the line was made fast to the stem of the boat, which was then drawn to the farther end of the reservoir; the required weight was put in the bucket, and on a signal being given, the boat was disengaged and drawn by the weight in the bucket to the opposite end of the reservoir, where it was stopped by a bag of cork shavings (*f*). In some of these experiments an additional weight was allowed to act on the boat for the first twenty feet, in order to get up the velocity; then it was cut off, and the boat went on with the uniform velocity; this was accomplished by putting a ring of lead (*x*,) weighing twenty pounds, on the top of the bucket holding the weights, and making this ring fast by four lines to the upper frame work, these lines being of sufficient length to allow the ring to act on the bucket, and to descend with it through a given space.

TABLE I.

Experiments made with different models on the sheet of water in the National Gallery of Practical Science, Adelaide Street, for the purpose of ascertaining the law of resistance or force of traction at different velocities.

Number of Experiments.	Weight of boat and cargo.	Space passed over with uniform velocity.	Time in seconds.	Miles per hour.	Moving power.	Force of traction, or weight on the towing line during each experiment	Force of traction, calculated as the squares of the velocities.	Difference between theory and experiment.	General Observations.
	lbs.	feet.	″		lb	lbs.			
1	39·25	30	9·8	2·087	1	0·468	0·468	—	The boat, when empty, weighed 22·19 lbs. She was made like the drawing plate III. of thin copper. Length 10 feet 2 inches, breadth at water line 8·5 inches, depth 3·5 inches, ditto immersed, when empty 1·5 inches.
2	„	„	9·6	2·130	„	„	0·487	+0·019	
3	„	„	9·4	2·176	„	„	0·508	+0·040	
4	„	„	9·8	2·087	„	„	0·468	—	
5	„	„	10·0	2·045	„	„	0·449	—0.019	
6	„	„	9·8	2·087	„	„	0·468	—	
7	„	„	9·8	2·087	„	„	0·468	—	
8	„	„	9·8	2·087	„	„	0·468	—	The standard adapted for calculating the squares of the velocities is 2·087 miles per hour.
		30		2·098	1	0·468	0·473	—	
9	„	30	7·0	2·922	5	1·000	0·917	—0·083	
10	„	„	7·0	2·922	„	„	0·917	—0·083	
11	„	„	7·0	2·922	„	„	0·917	—0·083	
12	„	„	7·0	2·922	„	„	0·917	—0 083	The weights 17·06 lb. consisted of lead shot in three bags, placed in the centre of the boat.
13	„	„	7·20	2 840	„	„	0·866	—0·134	
14	„	„	7·4	2·763	„	„	0·820	—0·180	
15	„	„	7·0	2·922	„	„	0·917	—0·083	
16	„	„	7·0	2·922	„	„	0·917	—0·083	
		30		2 892	5	1·000	0·898	—0·102	
17	„	30	6.2	3·299	10	1·718	1·169	—0·549	
18	„	„	6·2	3·299	„	„	1·169	—0·549	
19	„	„	6·0	3·409	„	„	1·248	—0·470	
20	„	„	6·4	3 195	„	„	1·096	—0·622	
21	„	„	6·2	3·299	„	„	1·169	-0·549	
22	„	,	6·2	3·299	„	„	1·169	—0·549	
23	„	„	6·4	3·195	„	„	1 096	—0·622	
24	„	„	6·2	3·299	„	„	1·169	—0·549	
25	„	„	6·0	3·409	„	„	1·248	—0·470	
26	„	„	6·2	3·299	„	„	1·169	—0·549	
27	„	„	6·4	3·195	„	„	1·096	—0·622	
		30		3·290	10	1·718	1·162	—0·556	

Number of Experiments.	Weight of boat and cargo.	Space passed over with uniform velocity.	Time in seconds.	Miles per hour.	Moving power.	Force of traction, or weight on the towing line during each experiment.	Force of traction, calculated as the squares of the velocities.	Difference between theory and experiment.	General observations.
	lbs.	feet.			lbs.	lbs.			
28	39·25	30	4·0	5·113	20	3·156	2·808	—0·348	
29	,,	,,	4·2	4·870	,,	,,	2·547	—0·609	
30	,,	,,	3·8	5·382	,,	,,	3·111	—0·045	
31	,,	,,	3·4	6·016	,,	,,	3·887	+0·731	
32	,,	,,	4·0	5·113	,,	,,	2·808	—0·348	
33	,,	,,	4·0	5·113	,,	,,	2·808	—0·348	
34	,,	,,	4·0	5·113	,,	,,	2·808	—0 348	
35	,,	,,	3·8	5·382	,,	,,	3·111	—0·045	
36	,,	,,	4·0	5·113	,,	,,	2·808	0 348	
37	,,	,,	4·0	5·113	,,	,,	2.808	—0·348	
		30		5·232	20	3·156	2·956	—0·216	
38	,,	30	2·8	7·305	40	5·812	5·731	—0·081	
39	,,	,,	2·8	7·305	,,	,,	5·731	—0·081	
40	,,	,,	3·0	6·818	,,	,,	4·992	—0·820	
41	,,	,,	2·8	7·305	,,	,,	5·731	—0·081	
42	,,	,,	3·0	6·818	,,	,,	4·992	—0·820	
43	,,	,,	2·8	7·305	,,	,,	5.731	—0·081	
44	,,	,,	2·8	7·305	,,	,,	5·731	—0 081	
45	,,	,,	2·8	7·305	,,	,,	5·731	—0·081	
46	,,	,,	2·8	7 305	,,	,,	5·731	—0·081	
		30		7·196	40	5·812	5·561	—0·251	
47	,,	30	2·2	9·297	60	8·500	9·283	+0·783	
48	,,	,,	2·0	10·227	,,	,,	11·233	+2·733	
49	,,	,,	2·2	9·297	,,	,,	9·283	+0·783	
50	,,	,,	2·2	9·297	,,	,,	9·283	+0·783	
51	,,	,,	2·0	10·227	,,	,,	11·233	+2·733	
52	,,	,,	2·0	9·297	,,	,,	9·283	+0·783	
		30		9·607	60	8·500	9·912	+1.412	
53	53·06	30	7·0	2·922	10	1·718	0 917	—0·801	
54	,,	,,	7·2	2·840	,,	,,	0·866	—0·852	
55	,,	,,	6·8	3·008	,,	,,	0 972	—0·746	
		30		2·923	10	1·718	0·918	—0·800	

Number of Experiments.	Weight of boat and cargo.	Space passed over with uniform velocity.	Time in seconds.	Miles per hour.	Moving power.	Force of traction, or weight on the towing line during each experiment.	Force of traction, calculated as the squares of the velocities.	Difference between theory and experiment.	General observations.
	lbs.	feet.	"		lbs.	lbs			
56	53·06	30	5·4	3·787	20	3·156	1·540	−1·616	
57	"	"	5·2	3·933	"	"	1·661	−1·495	
58	"	"	5·4	3·787	"	"	1·540	−1·616	
59	"	"	5·4	3·787	"	"	1·540	−1·616	
60	"	"	5·2	3·333	"	"	1·661	−1·495	
		30		3·845	20	3·156	1·588	−1.568	
61	22·19	30	3·0	6·818	20	3·156	4·992	+1·836	From experiment No. 61 to No. 72 the boat was empty.
62	"	"	3·0	6·818	"	"	4·992	+1·836	
63	"	"	2·9	7·053	"	"	5·342	+2·186	
64	"	"	3·2	6·392	"	"	4·388	+1·232	
65	"	"	3·1	6·598	"	"	4·675	+1·519	
66	"	"	3·2	6·392	"	"	4·388	+1·232	
67	"	"	3·0	6·818	"	"	4·992	+1·836	
68	"	"	3·2	6·892	"	"	4·388	+1·232	
		30		6·660	20	3·156	4·764	+1·608	
69	"	30	3·0	6·818	20	3·156	4·992	+1·836	An accelerating force of 10 lbs. was added for the first 30 feet of the canal, to bring the boat to her full speed before reaching the measured space of 30 feet.
70	"	"	3·0	6·818	"	"	4·992	+1·836	
71	"	"	3·1	6·598	"	"	4·675	+1·519	
72	"	"	3·0	6·818	"	"	4·992	+1·836	
		30		6·763	20	3·156	4·912	+1·756	
73	39·25	30	3·4	6·016	20	3·156	3·887	+0·731	Boat weighted. From No. 73 to No. 79, an accelerating force of 10 lbs. was given for the first 20 feet of the canal.
74	"	"	3·6	5·681	"	"	3·466	+0·310	
75	"	"	3·8	5·382	"	"	3·111	−0·045	
76	"	"	3·4	6·016	"	"	3·887	+0·731	
77	"	"	3·6	5·681	"	"	3·466	+0·310	
78	"	"	3·6	5·681	"	"	3·466	+0·310	
79	"	"	3·8	5·382	"	"	3·111	−0·045	
		30		5·691	20	3·156	3·478	+0·322	
80	"	30	3·8	5·382	20	3·156	3·111	−0·045	During Nos. 80, 81, and 82, the accelerating force was taken off.
81	"	"	4·0	5·113	"	"	2·807	−0·349	
82	"	"	3·6	5·681	"	"	3·466	+0·310	
		30		5·392	20	3·156	3·122	−0·034	

Number of experiments.	Weight of boat and cargo.	Space passed over with uniform velocity.	Time in seconds.	Miles per hour.	Moving power.	Force of traction, or weight in the towing line during each experiment.	Force of traction, calculated as the squares of the velocities.	Difference between theory and experiment.	General observations.
	lbs.	*feet.*	"		*lbs.*	*lbs.*			
83	39·25	30	2·8	7·305	40	5.812	5·731	—0.081	
84	"	"	2·7	7·575	"	"	6·162	+0·350	
85	"	"	2·7	7·575	"	"	"	+0·350	In the experiments, Nos. 86 and 87, an accelerating force of 10 lbs. was added.
86	"	"	2·7	7·575	"	"	"	+0·350	
87	"	"	2·7	7·575	"	"	"	+0·350	
		30		7·521	40	5·812	6·075	+0·263	
88	"	30	1·9	10·765	70	9·863	12·446	+2·583	
89	"	"	1·9	10·765	"	"	"	+2·583	
90	"	"	1·8	11·363	"	"	13·867	+4·004	
91	"	"	1·6	12·784	"	"	17·552	+7·689	
92	"	"	2·0	10·227	"	"	11·233	+1·370	
		30		11·180	70	9·863	13·424	+3·561	
93	"	30	1·9	10·765	80	11·217	12·446	+1·229	
94	"	"	1·8	11·363	"	"	13·867	+2·650	
95	"	"	1·8	11·363	"	"	"	+2·650	
96	"	"	1·8	11·363	"	"	"	+2·650	
97	"	"	1·8	11·363	"	"	"	+2·650	
98	"	"	1·6	12·784	"	"	17·552	+6·335	
99	"	"	1·6	12·784	"	"	"	+6·335	
100	"	"	1·6	12·784	"	"	"	+6·335	
101	"	"	1·6	12·784	"	"	"	+6·335	
		30		11·928	80	11·217	15·280	+4·063	
102	"	30	3·1	6·598	40	5·812	4·675	—1·137	One weight was placed in the centre of the boat; another weight 15 inches from the centre, forward; and a third weight 18 inches from the centre abaft.
103	"	"	3·0	6·818	"	"	4·992	—0·820	
104	"	"	2·7	7·575	"	"	6·162	+0·350	
105	"	"	3·6	5·681	20	3·156	3·466	+0·310	
106	"	"	3·8	5·382	"	"	3·111	—0·045	
107	"	"	3·6	5·681	"	"	3·466	—0·310	All the weights placed within 18 inches of the stern.
108	"	"	3·8	5·382	"	"	3·111	—0·045	
109	"	"	3·8	5·382	"	"	3·111	—0·045	
110	"	"	5·6	3·653	"	"	1·433	—1·723	
111	"	"	3·8	5·382	"	"	3·111	—0·045	The weights distributed as in experiment No. 102, &c.
112	"	"	3·8	5·532	"	"	3·111	+0·045	
113	"	"	3·9	5·245	"	"	2·954	—0·202	The weights placed 18 inches from the stern.
114	"	"	3·9	5·245	"	"	2·954	—0·202	
115	"	"	2·0	10·227	60	8·500	11·233	+2·733	The weights distributed as in experiment No. 102.
116	"	"	2·0	10·227	60	"	11·233	+2·733	The weights placed 18 inches from the stern.
117	"	"	2·0	10·227	60	"	11·233	+3·733	

Number of experiments.	Weight of boat and cargo.	Space passed over with uniform velocity.	Time in seconds.	Miles per hour.	Moving power.	Force of traction, or weight on the towing line during each experiment.	Force of traction calculated as the squares of the velocities.	Difference between theory and experiment.	General observations.
	lbs.	*feet.*			*lbs.*				
118	39·25	30	1·5	13·636	80	11·217	19·970	+8·753	Grahame boat-model. Weight of boat alone 22·19 lbs.; length, 10 ft. 2 in.; breadth at water line, 8·5 in.; depth, 3.5. in.; ditto, immersed when empty, 1·5 in. One weight 24 in. from the stern; a second weight 24 inches more forward; and a third 24 inches still more forward.
119	„	„	1·6	12·784	80	11·217	17·552	+6·335	
120	„	„	1·5	13·636	90	12·619	19·970	+8·351	
121	„	„	1·4	14·610	90	12·619	22·294	+10·305	
122	„	„	1·5	13·636	90	12·619	19·970	+7·351	
123	„	„	1·5	13·636	90	12·619	19·970	+7·351	
124	„	„	1·4	14·610	100	14·021	22·924	+8·903	
125	„	„	3·8	5·532	10	1·718			Bell boat model. Weight 9 lb. 13 oz.
126	„	„	4·0	5·113	10	1·718			
127	„	„	3·6	5·681	30	4·359			
128	„	„	3·0	6·818	50	7·265			
129	„	„	3·2	6·392	50	7·265			
130	„	„	3·6	5·681	50	7·265			
131	„	„	2·6	7·867	10	1·718			Ardrossan boat-model. Weight 6 lb. 3 oz. Length 5 feet. Breadth at water line 4 in. Depth 1·5 inches. Depth immersed 0·5 in.
132	„	„	2·8	7·305	10	1·718			
133	„	„	2·6	7·867	10	1·718			
134	„	„	1·8	11·363	20	3·156			
135	„	„	1·8	11·363	20	3·156			

It will be observed in the above tables, that as the velocity was increased, the power did not require to be increased in any thing like the duplicate ratio, and that the difference shown in the above column, betwixt the theory of the duplicate ratio, and actual experiment, becomes greater, as the velocity is increased. I select from these experiments the following as instances. They are not taken from the means, but from the *items* of the experiments themselves.

At a velocity of 2.763 miles per hour 1. lb. is required, or .180 *more* than the theory of the square.
. . . . . 5.382 . . . . 3.156 lb. . . . . .045 „ ditto.

At a velocity of 5.382 miles per hour 3.156 lb. is required, or .045 *more* than the theory of the square.
. . . . . 10.765 . . . . 9.863 lb. . . . 2.583 *less* ditto.

At a velocity of 6.392 miles per hour 3.156 lb. is required, or 1.232 *less* than the theory of the square.
. . . . 12.784 . . . . 11.217 lb. . . . 6.335 „ ditto.

I call attention particularly to these individual experiments, in order that the wide deviation may be noticed, and serve to shake the confidence, still entertained by the adherents of the old school, who cannot allow that a high velocity is attainable upon canals with economy. Not that I consider the old law of the squares to be incorrectly stated; in so far as the boat remains immersed in the water to the same water-line, that law may be correct,—but that whenever the velocity of the boat is increased beyond a certain point, as will be seen hereafter, the boat emerges a little out of the water, and skims nearer the surface. The transverse section of immersion being lessened. This will be proved as we proceed.

Such facts being obtained and found to differ so widely from the opinions of philosophers, it was exceedingly desirable that they should not go forth to the public, without the fullest confirmation. Happily for science, Colonel Page, Chairman of the Kennett and Avon Canal Company, to whose exertions and liberality it is entirely owing, induced the principal canal companies in England* to subscribe towards paying the expenses of an extended course of experiments with a large boat. I accordingly proceeded to Scotland, and purchased one of the Paisley Canal Company's quick boats, "the Swallow," which we afterwards named the "Grahame and Houston," in compliment to the two gentlemen who have been so eminently successful in improving the canal conveyance of Scotland. Indeed, Mr. Grahame's letters on the subject of canal navigation will furnish the most satisfactory reason why we should have used his name for the boat.

With this boat the results exhibited in the following tables (II. III. IV.) were obtained on the Paddington Canal, opposite Holsden Green. The important effects, which they are calculated to produce, in the minds of the unprejudiced, not only upon inland navigation, but to nautical science in general, have determined me to publish them in the fullest manner, giving every particular connected with their arrangement, as well as the names of those scientific gentlemen who assisted me, together with the names of the assistants from my own office. So that the most ample evidence of accuracy and care may be had. For more advantage will be derived by accurate trains of experiments than will follow from the assumptions of a mathematical century.

The first requisite was a good dynamometer for measuring the tractive force necessary to move the boat at various velocities, and as I showed a marked preference for my own, with which I had obtained such important results during

* The Grand Junction, the Kennett and Avon, the Aire and Calder, the Oxford, and the Leeds and Liverpool.

my surveys of roads for the parliamentary commissioners, I shall give a description of it, in order that readers may be satisfied such preference was justly given.

The dynamometer or pirameter, I originally intended for measuring the draught of carriages on turnpike roads, and for this purpose I have used it very extensively under the Parliamentary Commissioners for the London and Holyhead road and elsewhere. The following is a description of the instrument, and in the Appendix (B.) will be found the opinions of competent judges upon its merits. When I at first endeavoured to adapt Marriot's spring weighing machine, so as to ascertain from it, the amount of the horses draught, the stepping motion of the horse created a quick succession of vibrations, which completely prevented any one from reading off the figures indicated—and this confusion of vibrations will always prevent the simple adoption of any species of spring weighing machine. To remedy this inconvenience, and do away with the vibrations as much as was necessary, I applied a piston, working in a cylinder full of oil, and connected with the spring in such a manner that when any power or force is applied to it so as to make the hand traverse the index, the piston is at the same time moved through the fluid. The connection of the spring and index with the cylinder, is by means of a lever working on a pivot: the arms of the lever are of unequal length; the tail-piece of the spring and index is connected with the short arm; at the extremity of the long arm, the piston rod is connected; the piston rod, after passing through a stuffing box in the cap of the cylinder, is screwed into a piston, or circular plate of thin brass, perforated with small holes; and out of one part of the circumference a square notch is cut, the use of which will be seen below.

By this construction, the resistance of the fluid to the piston, which acts at the extremity of the long arm of the lever, prevents the sudden jerks of the horse from being marked with those vibrations on the index, so much to be avoided; at the same time the piston will move over a space proportioned to the intensity of the force exerted by the horse, and the same will be indicated accordingly upon the dial of the instrument; if the pulls follow each other in rapid succession, the piston will move slowly out, and the hand upon the index will turn round steadily and uniformly, until the power is balanced by the spring.

The dial is graduated in pounds, and decreases from Zero upwards, in order to compensate for the increased force, which the spring exerts in proportion as it s wound up; in consequence of this the index does not pass over equal spaces when equal forces are applied in different states of tension of the spring; the piston, therefore, will not pass through equal spaces in the cylinder, and the vibrations would consequently be greater in the higher numbers, because the velocity of the piston being less, the resistance to the piston, in passing the fluid will be less, at the same time the power opposed to it is greater. To obviate this, and to make the index equally steady on all parts of the dial, a narrow slip of brass formed into an inclined plane, is soldered to the inside of the cylinder, parallel to its axis, the largest (or highest) part of this inclined plane, being at that end of the cylinder, towards which the piston rises when the index moves towards the greater power. The notch, which is said above to be cut in the circumference of the plate, (which traverses like a piston in this cylinder,) corresponds in size exactly with the largest part of this inclined plane; so that when the piston is at the upper end of the cylinder, the notch is completely filled up by the inclined plane; on the contrary, when the piston is at the lower end of the cylinder, the aperture is completely opened. By this contrivance the aperture, through which the fluid is obliged to pass, as the piston moves from the lower end of the cylinder to the higher, is gradually contracted, and of course the resistance to the passage of the piston through the fluid is gradually increased, and thus compensates the increased power of the spring; rendering the vibrations nearly uniform from the lowest to the higest power. This compensation is similar to that by which the fusee regulates and gives uniform power to the main-spring of a watch.

This instrument* was placed in the door-way of the front cabin, (which is about fourteen feet from the stem of the boat,) and in a line with the ordinary tugging hook; secured with wooden braces and screw nails in such manner as to be perfectly firm and steady. In some instances the towing line was made fast to the weighing-bar of the dynamometer, and the power communicated directly to it. In other cases the towing-line was made fast to a shackle on an iron lever, the fulcrum of which was the screw-bolt which made the bar fast to the gunwale of the boat, on the bow nearest the towing-path; the power being communicated from the lever to the dynamometer by means of another shackle; this last mentioned shackle being precisely twice the distance from the fulcrum. By this arrangement we were enabled to bring either the whole tractive force to be indicated on the dial-plate at once, or only one half that power, as we pleased,—by merely shifting from one position to the other.

I considered this arrangement to be advisable, lest by any chance there should have been an error in the graduation of the dynamometer. To prove its accuracy, we repeated most of the experiments with and without the lever. If when the power was communicated to the weighing bar of the dynamometer, the instrument indicated the whole traction to be one hundred pounds, and if when the power was communicated to the other shackle, the instrument indicated only fifty pounds,

* In the modification of this instrument which I have now mounted in a light double-bodied phæton, the dial-plate is fitted, not only with an index and hand, but also with a card for determining the bearing; a pendulum which shows, by means of an index and hand, the inclination; a time-piece; and an index and hand to show the distance travelled by the wheels.—See Appendix B.

we were warranted in concluding that, as far as this experiment was concerned, the dynamometer was accurate. Now this I had done on numerous occasions, to prevent the possibility of error; and in order to be more perfectly assured, I repeatedly employed weights, suspended over a pulley, to check the dynamometer.

In making the observations with the dynamometer, every care was taken to have accuracy. Mr. Whitwell kindly assisted me in all these observations. He took the time with an excellent watch, having a detached second hand, with a dead beat; which enabled him to give a signal very accurately at intervals of two seconds. At these signals the power of traction indicated by the dynamometer was read off silently and distinctly by two gentlemen, whose names are at the head of their respective copies. Each of these gentlemen added the observations together, and took the means of each set.

Whilst these observations were making at the fore-sheets of the boat, the times of the boat's passage were noted a little farther aft, by Mr. Turnbull and Mr. Dundas, who had each an excellent chronometer (from Arnold and Dent's.) The word "*time*" was given by Mr. Wilson, when the boat passed the stakes which had previously been driven in the embankment at distances of one hundred yards apart. By this means the observers of the time had never occasion to lift their eyes from the chronometers, except to note down the observations.

Besides the gentlemen making these observations, I was always assisted by others; but more especially by Mr. Alexander Gordon and Mr. Saxton, both of whom being so well qualified, from their practical and scientific acquirements, for such a series of experiments, contributed very materially to prevent errors from taking place, by a general view over each department.

Plate 2, represents five transverse sections of the Paddington canal, opposite the village of Holsden Green, beginning at bridge No. 6, and proceeding westward; the soundings and measurements having been taken by Mr. Bourns and Mr. Turnbull; upon which part of the canal the following experiments were made.

Plate 3, shows the dimensions and general appearance of the iron boat, "Grahame and Houston," with which all the following experiments were made. In Appendix A will be found a specification of the manner in which these boats are built.

TABLE II.

Experiments made with the "Grahame and Houston" Iron Boat, on the Paddington Canal, for the purpose of ascertaining the law of resistance, or force of traction at different degrees of Velocity. 8th April, 1833.

No. of Experiment.	Time of passing each Stake by Chronometer No. 385. Dundas.	Time of passing each Stake by Chronometer No. 583. Turnbull.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 385.	Interval of Time occupied in passing over the distance of 100 yards between each Stake by No. 583.	Mean Time of passing over 100 yards between each Stake.	Velocity in Miles per hour.	Force of Traction in lbs. as observed by Mr. Bourns.	Force of Traction in lbs. as observed by Mr. Baker.	Mean Force of Traction in lbs. as observed.	Mean Force of Traction calculated from the squares of the Velocities.	Mean Force of Traction calculated from the cubes of the Velocities.	Weight of Passengers in lbs.	Observations.
	h. m. s.	h. m. s.	"	"	"								
*	1 55 6·5	1 55 5·5											
11	1 55 48·5	1 55 47·5	42·5	42·0	42·25	4·841	75·00	75·0	75·				
12	1 56 29	1 56 28	40·5	40·5	40·5	5·050	69·74	70·0	69·87				Wind a-head, but scarcely perceptible.
13	1 57 9	1 57 8	40·0	40·0	40·0	5·113	66·50	66·50	66·50				
14	1 57 52·5	1 57 51·5	43·5	43·5	43·5	4·702	47·32	47·20	47·26				
15	2 5 38·0	2 5 37·0				4·955			61·21	97·90	192·58	2511	
16	2 6 15·5	2 6 14·5	37·5	37·5	37·5	5·454	111·33	112·2					
17	2 6 52·0	2 6 51	36·5	36·5	36·5	5·603	128·53	132·4	130·46				
18	2 7 29·0	2 7 27·5	37·0	36·5	36·75	5·565	149·23	151·0	150·11				
19	2 8 5·0	2 8 3·5	36·0	36·0	36·0	5·681	143·55	144·0	143·77				
20	2 19 44·5	2 19 43·5				5·616			141·44	125·94	280·38	2511	
21	2 20 13·5	2 20 12·5	29·0	29·0	29·0	7·053	141·76	139·50	140·53				
22	2 20 42·0	2 20 41·0	28·5	28·5	28·5	7·177	121·12	124·4	122·76				
23	2 21 9·5	2 21 8·5	27·5	27·5	27 5	7·437	120·54	118·8	119·67				
24	2 21 36·5	2 21 35·0	27·0	26·5	26·75	7·646	107·46	107·5	107·48				
25	2 31 38·5	2 31 37·5				7·420			116·63	219·09	646·68	2511	
26	2 32 5·5	2 32 4·5	27·0	27·0	27·0	7·575	169·74	172·0	170·87				
27	2 32 31	2 32 30	25·5	25·5	25·5	8·021	139·58	140·5	140·04				
28	2 32 56	2 32 55	25·0	25·0	25·0	8·181	136·76	137·2	136·98				
29	2 33 21	2 33 20	25·0	25·0	25·0	8·181	144·72	144·6	144·66				
30	2 41 20·5	2 41 19·5				8·127			140·56	262·83	849·71	2511	
31	2 41 42·5	2 41 41·0	22	21·5	21·75	9·404	228·36	224·2	226·28				
32	2 42 5·0	2 42 4·0	22·5	23·0	22·75	8·990	209·16	214·0	211·58				
33	2 42 28·0	2 42 27·0	23·0	23·0	23·0	8·893	185·00	181·8	183·40				
34	2 42 51	2 42 50·0	23·0	23·0	23·0	8·893	176·92	183·5	180·21				
35	2 56 7	2 56 6·0				8·925			191·73	314·80	1125·38	2511	
36	2 56 57·5	2 56 56·25	50·5	50·25	50·37	4·060	49·84	50·4	50·12				
37	2 57 45	2 57 43·5	47·5	47·25	47·37	4·318	50·08	49·6	49·84				
38	2 58 32·5	2 58 31·0	47·5	47·5	47·5	4·306	42·58	42·6	42·59				
39	2 59 22·5	2 59 21·5	50·0	50·5	50·25	4·070	43·40	43·2	43·30				
40	3 7 53·0	3 7 52·0				4·231			45·24	71·24	119·89	2711	
41	3 8 16·0	3 8 15·0	23·0	23·0	23·0	8·893	240·14	230·0	235·07				
42	3 8 35·0	3 8 34·0	19·0	19·0	19·0	10·765	282·00	280	281·00				
43	3 8 53·0	3 8 52·0	18·0	18·0	18·0	11·363	302·44	304·5	303·47				
44	3 9 11·0	3 9 10·0	18·0	18·0	18·0	11·563	276·88	279·4	278·14				
						11·163			287·53	496·10	2202·02	2711	

* The first ten experiments are not published, because the arrangements were not, at that time, as perfect as could be wished.

	feet.	girth.	weight.
Length of horse line . . .	82·1	1·7-8ths	10 lb. 1 oz.
Length of light line . . .	68·1	7-8ths	2 8

TABLE II.—*Continued.*

No. of Experiment.	Time of passing each Stake by Chronometer No. 385. Dundas.	Time of passing each Stake by Chronometer No. 583. Turnbull.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 385.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 583.	Mean Time of passing over 100 yards between each Stake.	Velocity in Miles per hour.	Force of Traction in lbs., as observed by Mr. Bourns.	Force of Traction in lbs., as observed by Mr. Baker.	Mean Force of Traction in lbs., as observed.	Mean Force of Traction, calculated from the squares of the Velocities.	Mean Force of Traction, calculated from the cubes of the Velocities.	Weight of Passengers in lbs.	Observations.
	h. m. s.	h. m. s.	"	"	"								
45	3 25 52	3 25 51·5	20	19·5	19·75	10.356	329·10	334·0					
46	3 26 12	3 26 11	17·5	17·5	17·5	11·688	303·32	315·0	309·16				
47	3 26 29·5	3 26 28·5	18·5	18·5	18·5	11·056	327·78	295·0	311·39				
48	3 26 48	3 26 47	19·5	19·5	19·5	10·489	263·64	260·0	261·82				
	3 27 7·5	3 27 6·5											
49						11·077			294·12	488·83	2139·2	2711	
50	4 6 24	4 6 23	96·5	96·5	96·5	2·119	23·46	23·2					Tracked by one man.
51	4 8 0·5	4 7 59·5	91·0	91·0	91·0	2·247	23·10	23·8	23·45				
52	4 9 31·5	4 9 30·5	94·5	94·0	94·25	2·170	23·70	23·8	23·75				
53	4 11 6	4 11 4·5	92·0	92·5	92·25	2·217	22·80	23·8	23·3				
	4 12 38	4 12 37											
54						2·211			23·5	19·47	17·04	2711	
55	4 24 5·5	4 24 4·5	53·75	53·75	53·75	3·805	49·54	50·0					Tracked by three men.
56	4 24 59·25	4 24 58·25	57·25	57·25	57·25	3·572	47·16	47·4	47·28				
57	4 25 56·5	4 25 55·5	56·5	56 5	56·5	3·620	47·16	47·2	47·18				
58	4 26 53	4 26 52	56·5	55·5	56·0	3·652	45·08	45·0	45·04				
	4 27 49·55	4 27 47·5											
59						3·614			46·5	52·03	74·43	2711	
60	5 4 54	5 4 52·5	24·5	24·5	24·5	8·349	203·52	203·5					Tracked by two horses.
61	5 5 18·5	5 5 17	23·5	23·5	23·5	8·704	173·34	176·6	174·97				
62	5 5 42	5 5 40·5	23·0	23·5	23·25	8·797	193·32	193·5	193·41				
63	5 6 5	5 6 4	23·5	23·0	23·25	8·797	174·16	174·2	174·18				
	5 6 28·5	5 6 27											
						8·766			180 85	306·14	1179·74	2711	

The standard adopted for calculating the squares and cubes of the velocities in the above experiments, and all those made on the Paddington Canal, was 2·517 miles per hour.

TABLE III.

Experiments made with the "Graham and Houston" Iron Boat, on the Paddington Canal, for the purpose of ascertaining the law of resistance, or force of traction, at different degrees of velocity. 9th April, 1833. 15 *Passengers.*

No. of Experiment.	Time of passing each Stake by the Chronometer, No. 385. Turnbull.	Time of passing each Stake by the Chronometer, No. 533. Dundas.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 385.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 533.	Mean Time of passing over 100 yards between each Stake.	Velocity in Miles per hour.	Force of Traction in lbs., as observed by Mr. Bourns.	Force of Traction in lbs., as observed by Mr. Baker.	Mean Force of Traction in lbs., as observed.	Mean Force of Traction calculated from the squares of the velocity.	Mean Force of Traction calculated from the cubes of the velocity.	Weight of Passengers in lbs.	Observations.
	h. m. s.	h. m. s.	"	"	"								
1	12 54 6	12 54 4	73	73	73	2·801	29·72	29·75	29·73			2381	Tracked by one man.
2	12 55 19	12 55 17	77	77·5	77·25	2·647	26·27	26·25	26·21				....
3	12 56 36	12 56 34·5	84	83	83·5	2·449	25·8	25·4	25·6				....
4	12 58 0	12 57 57·5	83	83·5	83·25	2·456	24·3	23·5	23·9				....
	12 59 23	12 59 21											
						2·517			25·24	25·24	25·24		
5	1 23 11·5	1 23 8·5	83·5	84·5	84	2·435			21 lbs. (5–8)			Weight the same throughout.	.... These four experiments were made by a weight over a pulley; no accurate result.
6	1 24 35	1 24 32·5	80·5	80·5	80·5	2·540							....
7	1 25 55·5	1 25 53	76·5	76·5	76·5	2·673							....
8	1 27 12	1 27 9·5	79·0	78·5	79·25	2·580							....
	1 28 31	1 28 28											
						2·597			21	26·87	27·72		
9	1 41 18·5	1 41 16	68·5	68	68·25	2·977	34·8	35·2	35				Tracked by two men.
10	1 42 27	1 42 24	68	68	68·0	3·008	26·2	26·2	26·2				....
11	1 43 35	1 45 32	63	63·5	63·25	3·233	33·9	33·7	33·8				....
12	1 44 38	1 44 35·5	65	64·5	64·75	3·158	30·0	29·9	29·95				....
	1 45 43	1 45 40											
						3·133			29·98	39·10	48·67		
13	1 56 26·5	1 56 23·5	67·5	67·5	67·5	3·030			33 lbs. (13–16)				.... These four experiments were made with a weight over a pulley.
14	1 57 34	1 57 31	69	69	69·0	2·964							....
15	1 58 43	1 58 40	67·5	68	67·75	3·019							....
16	1 59 50·5	1 59 48	73·5	73	73·25	2·791							....
	2 1 4	2 1 1											
						2·924			30	34·06	39·57		
17	2 10 ·47	2 10 44	48·5	48·5	48·5	4·217	59·5	59·3	59·4				Tracked by two horses.
18	2 11 35·5	2 11 32·5	48	48·0	48·0	4·261	56·1	57·15	56·62				....
19	2 12 23·5	2 12 20·5	45·5	45·5	45·5	4·217	62·17	63·5	62·83				....
20	2 13 9	2 13 6	44	44	44·0	4·648	65·75	65·25	65·5				....
	2 13 53	2 13 50											
						4·375			61·65	76·25	132·55		
21	2 28 55	2 28 51·5	52·0	52	52·0	3·933			58 lbs. too little by 10. (21–24)				....
22	2 29 47	2 29 43·5	45·5	45·5	45·5	4·495							....
23	2 30 32·5	2 30 29	43·5	44	43·75	4·675							....
24	2 31 16	2 31 13	44·5	44	44·25	4·622							....
	2 32 0·5	2 31 57											
						4·597							
25	4 29 58·5	4 29 3	21	22	21·5	9·513	267·00	267·0	267·0				....
26	4 30 19·5	4 30 15	21·5	21	21·25	9·625	238·54	238·50	238·52				....
27	4 30 41	4 30 36	22	22	22·0	9·297	228·20	228·20	228·20				....
28	4 31 3	4 30 58	21·5	22	21·75	9·404	230·76	232·20	231·48				....
	4 31 24·5	4 31 20											
						9·442			232·73	355·18	1332·51		
29	4 39 6	4 39 1	16·5	16·5	16·5	12·396	437·0	436·88	436·94				....
30	4 39 22·5	4 39 17·5	17	17	17 0	12·032	397·32	384· ?	395·66 ?				....
	4 39 39·5	4 39 34·5											....
31	4 39 59	4 39 54	19·5	19·5	19·5	10·489	302·4	298·12	300·26				....
32	4 40 19	4 40 14	20	20	20·0	10·277	271·0	270·90	270·5				....
						10·383			285·15	429·50	1771·93		

TABLE III.—*Continued.*

No. of Experiment.	Time of passing each Stake by Chronometer No. 385. Turnbull.	Time of passing each stake by Chronometer, No. 533. Dundas.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 385.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 533.	Mean Time of passing over 100 yards between each Stake.	Velocity in Miles per hour.	Force of Traction in lbs., as observed by Mr. Bourns.	Force of Traction in lbs., as observed by Mr. Baker.	Mean Force of Traction in lbs., as observed.	Mean Force of Traction calculated from the squares of the Velocities.	Mean Force of Traction calculated from the cubes of the Velocities.	Weight of Passengers in lbs.	Observations.
	h. m. s.	h. m. s.	"	"	"								
	4 56 12·5	4 56 7											
33			18	18·5	18·25	11·207	403·6	403·6	403·6			2381	Tracked by two horses, large line.
	4 56 30·5	4 56 25·5											
34			19·5	18·75	19·12	10·697	344·8	344·8	344·8				
	4 56 50	4 56 44											
35			20	20·5	20·25	10·100	273·0	273·0	273·0				
	4 57 10	4 57 4·5											
36			22	22·0	22·0	9·297	246·0	245·5	245·75				
	4 57 32	4 57 26·5											
						10·031			287·85	400·87	1597·77	..	
37	5 10 9	5 10 3											
			75·5	75·5	75·5	2·709	27·19	27·5	27·34				
38	5 11 26·5	5 11 18·5											
39			77·5	77·5	77·5	2·638	25·22	25·2	25·21				
	5 12 42	5 12 36											
40			81·0	81·0	81·0	2·525	21·77	22·25	22·01				
	5 14 3	5 13 57											
			86·0	86·0	86·0	2·378	23·15	22·5	22·82				
41	5 15 29	5 15 23											Boat tracked by two men.
						2·513			23·34	25·16	25·12	..	
42	5 24 18·5	5 24 12											
43			61·5	62·0	61·75	3·312	37·56	37·15	37·35				
	5 25 20	5 25 14											
44	5 26 24·5	5 26 18·5											
			64·5	64·5	64·5	3·171	32·32	32·4	32·36				
45			64·5	64·0	64·25	3·183	32·06	32·4	32·23				
	5 27 29	5 27 22·5											
			65·0	65·0	65·0	3·146	30·30	30·0	30·15				
46						3·166			31·58	39·93	50·23	..	
	5 28 34	5 28 27·5											
47	5 57 17	5 57 10											
48			17	17	17	12·032	340	361·8	350·9				
	5 57 34	5 57 27											
49			17	17	17	12·032	338	337·5	337·75				
	5 57 51	5 57 44											
			18·5	18·5	18·5	11·056	320	315·6	318·3				
50			20·5	20·5	20·5	9·977	279·1	274	276·55				
	5 58 9·5	5 58 2·5											
51	5 58 30	5 58 23											
52						11·021			310·86	483·90	2119·05	..	
	6 11 48·5	6 11 40·5	..										
53			26	26·5	26·25	7·792	187·5	191·5	189·5				
	6 12 14·5	6 12 7·0											
54			27	27	27	7·575	148·2	149·2	148·7				
	6 12 41·5	6 12 34											
55			26·5	26·5	26·5	7·718	147·3	147·15	147·22				One horse employed to track the boat.
	6 13 8	6 13 0·5											
56			26·0	26·0	26·0	7·867	149·2	148·5	148·85				
	6 13 34	6 13 26·5											
			·			7·72			148·26	237·44	728·33	..	
57	6 26 37·5	6 26 29·5											
			36·5	36·5	36·5	5·603	133·68	132·0	132·84				
58	6 27 14	6 27 6											
59			38·0	38·5	38·25	5·347	138·33	132·2	135·26				
	6 27 52	6 27 44·5											
60			34·0	34·0	34·0	6·016	153·53	157·3	155·41				
	6 28 26	6 28 18·5											
			38·5	38·0	38·25	5·347	157·04	152·0	154·52				
61	6 29 4·5	6 28 56·5											
						5·57			148·39	123·60	273·54	..	
62	6 38 3·5	6 37 55											
63			26	26·5	26·25	7·792	202·85	195·3	199 07				
	6 38 29·5	6 38 21·5											
64	6 38 55·5	6 38 47											
			26	25·5	25·75	7·943	161·7	157·6	159·65				
65			26·5	27·0	26·75	7·646	148·9	149·5	149·2				
	6 39 22	6 39 14											
			25·5	25·0	25·25	8·100	149·64	145·6	147·62				
66						7·896			152·15	248·38	779·28	..	
	6 39 47·5	6 39 39											
	6 58 9	6 58 0·5											
67			34	33·5	33·75	6·060	137·94	138					
	6 58 43	6 58 34											
68	6 59 18·5	6 59 9·5	35·5	35·5	35·5	5·761	162·22	162·5	168·58	139·48	327·93	..	
69	59 52	6 59 43·0	33·5	33·5	33·5	6·105	170·59	170·75					
70	7 0 26·5	7 0 18·0	34·5	35·0	34·75	5·886	172·06	172·5					
						5·917							

TABLE IV.

Experiments made with the "Grahame and Houston" Iron Boat on the Paddington Canal, for the purpose of ascertaining the law of resistance, or force of traction, at different degrees of Velocities.—17th April, 1833.

No. of Observation.	Time of passing each Stake by Chronometer, No. 385. Dundas.	Time of passing each Stake by Chronometer No. 533. Turnbull.	Interval of Time occupied in passing over the distance of 100 yards between each Stake by No. 385.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 533.	Mean Time of passing over 100 yards between each Stake.	Velocity in Miles per hour.	Force of Traction in lbs., as observed by Mr. Baker.	Mean Force of Traction in lbs., as observed.	Mean Force of Traction, calculated from the squares of the Velocities.	Mean Force of Traction, calculated from the cubes of the Velocities.	Weight of Passengers in lbs.	Observations.
	h. m. s.	h. m. s.	"	"	"							
	11 35 17	11 35 17½	34·5	34	34·25	5·972	Dead Weight over a Pulley.				2381	
	11 35 51·5	11 35 51·5	35·5	35·5	35·00	5·844	154					
	11 36 27	11 36 27	36·0	36·0	36·00	5·681						
	11 37 3	11 37 3	36·5	36	36·25	5·642						
	11 37 39·5	11 37 40										
1						5·722	147	147·00	130·44	296·56	..	
	11 46 8·5	11 46 9	27·0	27	27·00	7·575						
	11 46 35·5	11 46 36	28	28	28·00	7·305	154					
	11 47 3·5	11 47 4	30	29·5	29·75	6·875						
	11 47 33·5	11 47 33·5	29·5	30·5	30·00	6·818						
	11 48 3	11 48 4										
2						6·999	154	154·00	195·16	542·73	..	
	11 55 53	11 55 53·5	24·5	24·5	24·50	8·348						
	11 56 17·5	11 56 18	23·5	23·5	23·50	8·704	190					
	11 56 41	11 56 41·5	23·5	23·5	23·50	8·704						
	11 57 4·5	11 57 4·5	27·5	28·0	27·75	7·371						
	11 57 32	11 57 32·5										
3						8·259	190	190·00	271·75	891·79	..	
	12 6 11	12 6 11·5	43	43	43·00	4·756						
	12 6 54	12 6 54·5	36	35·5	35·75	5·721	150					
	12 7 30	12 7 30·5	38·5	38·5	38 50	5·313						
	12 8 8·5	12 8 9	37·5	37·5	37·50	5·454						
	12 8 46	12 8 46·5										
4						5.496	150	150·00	120·34	262·79	..	
	12 38 13·5	12 38 14	32	32·5	32·25	6·342						
	12 38 45·5	12 38 46·5	34	33·5	33·75	6·060	175					
	12 39 19·5	12 39 20	31·5	31·5	31·50	6·493						
	12 39 51	12 39 51·5	33·5	33·5	33·50	6·105						
	12 40 24·5	12 40 25										
5						6·219	175	175·00	154·08	380·74	..	
	12 45 50	12 45 50·5	39	39	39·00	5·243						
	12 46 29	12 46 29·5	36	36	36·00	5·680	150					
	12 47 5	12 47 5·5	35	35·5	35·25	5·602						
	12 47 40	12 47 41	38	37·5	37·75	5·418						
	12 48 18	12 48 18·5										
6						5·533	150	150·00	126·41	282·94	..	
	1 31 12·5	1 31 13·5	24	24·5	24·25	8·434						
	1 31 36·5	1 31 37	22·5	22·5	22·50	9·090	200					
	1 31 59	1 31 59·5	23	23·5	23·25	8·797						
7	1 32 22	1 32 23	27	27	27·00	7·575						
	1 32 49	1 32 50										
						8·487	200	206·00	286·96	967·70	..	

TABLE IV.—*Continued.*

No. of Observation.	Time of passing each Stake by Chronometer No. 385. Dundas.	Time of passing each Stake by Chronometer No. 533. Turnbull.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 385.	Interval of Time occupied in passing over the distance of 100 yards between each Stake, by No. 533.	Mean Time of passing over 100 yards between each Stake.	Velocity in Miles per hour.	Force of Traction in lbs., as observed by Mr. Bourns.	Force of Traction in lbs., as observed by Mr. Baker.	Mean Force of Traction in lbs., as observed.	Mean Force of Traction calculated from the squares of the Velocities.	Mean Force of Traction calculated from the cubes of the Velocities.	Weight of Passengers in lbs.	Observations.
	h. m. s.	h. m. s.	"	"	"								
	1 45 21·5	1 45 22·5	32·5	32·5	32·50	6·293		Weight over a Pulley.				2381	
	1 45 54	1 45 55	32·5	32·5	32·50	6·293							
	1 46 26·5	1 46 27·5	36	36·5	36·25	5·642		154					
8	1 47 3	1 47 3·5	36·5	36	36·25	5·642							
	1 47 39	1 47 40											
						5·859		154	154.00	136·76	318·38	..	
	1 56 35	1 56 36	26·5	26·5	26·50	7·718							
	1 57 1·5	1 57 2·5	25·5	25	25·25	8·100							
	1 57 27	1 57 27·5	25	25	25·00	8·181		164					
9	1 57 52	1 57 52·5	26	26·5	26·25	7·792							
	1 58 18	1 58 19											
						8·024		164	164·00	256·50	817·80	..	
	2 9 29·5	2 9 30	32	32·5	32·25	6·342							
	2 10 1·5	2 10 2·5	34	34	34·00	6·016		154					
	2 10 35·5	2 10 36·5	35	35	35·00	5·844							
10	2 11 10·5	2 11 11·5	32	32	32·00	6·392							
	2 11 42·5	2 11 43·5											
						6·084		154	154·00	147·46	356·49	..	
	2 29 34	2 29 35	33·5	33	33·25	6·151	131·13	129·75	130·44				
	2 30 7·5	2 30 8	34	34	34·00	6·016	155·00	155·2	155·1				
	2 30 41·5	2 30 42	31·5	32	31·75	6·442	163·93	164·75	164·34				
11	2 31 13	2 31 14	34·5	34·5	34·50	5·928	162·14	161·25	161·69				
	2 31 47·5	2 31 48											
						6·128			160·37	149·61	364·27	..	
	2 47 23·5	2 47 24·5	23·5	24	23·75	8·612	197·00	196·91	196·95				
	2 47 47	2 47 48·5	23	22·5	22·75	8·991	198·58	198·50	198 54				
	2 48 10	2 48 11	23·5	23·5	23·50	8·704	198·75	199·0	198·89				
12	2 48 33·5	2 48 34·5	24·5	24·5	24·50	8·348	191·00	191·1	191·05				
	2 48 58	2 48 59											
						8·681			196·16	300·23	1035·58	..	
	3 5 35	3 5 36	35·5	36	35·75	5·721	124·53	116·9	120·36				
	3 6 10·5	3 6 12	34·5	34	34·25	5·972	141·83	138·69	138·69				
	3 6 45	3 6 46	33·5	33·5	33·50	6·105	152·17	151·77	151·97				
13	3 7 18·5	3 7 19·5	40	40	40·00	5·113	132·64	135·0	133·82				
	3 7 58·5	3 7 59·5											
						5·730			141·49	130·80	297·80	..	
	3 18 13·5	3 18 14·5	40	40·5	40·25	5·081	86·50	88·5	87·27				
	3 18 53·5	3 18 55	39·5	39	39·25	5·211	160	159·30	159·64				
	3 19 33	3 19 34	40·5	40·5	40·50	5·050	155·70	155·70	155·70				
14	3 20 13·5	3 20 14·5	38	38	38·00	5·382	161·58	161·52	161·04				
	3 20 51·5	3 20 52·5											
						5·214			158·79	108·30	224·38	..	
	4 2 48	4 2 49	27	27	27·00	7·575		150·75	150·75				
	4 3 15	4 3 16	26·5	27	26·75	7·646		153·75	153·75				
	4 3 41·5	4 3 43	25·5	25	25·25	8·100		151·25	151·25				
15	4 4 7	4 4 8	27	27	27·00	7·575		155·00	155·00				
	4 4 34	4 4 35											
						7·773			153·33	240·71	743·43	..	

It will be seen by the above tables that the results which have been obtained with the several boats are very different from those which might have been expected, supposing the resistance to them when passing the water to have been governed by the same laws which govern a uniform surface moved through the water with different degrees of velocity; but, the formulæ which are applicable to bodies presenting always the same cross section to the resistance of the fluid, are by no means applicable to bodies which at high velocities are raised considerably out of the water, and therefore present a less cross section to the action of the resisting medium. From this circumstance it will at once be seen that these experiments have little or no connexion or similarity with those made by Mr. Walker, or Mr. Palmer;* or with those of the celebrated French mathematicians, Bossut and Condercet; except in the lower velocities, between one and a half and three and a half miles an hour. Within the range of these velocities, or even up to four and a half miles an hour, the light boat is not, or, at least, is very imperceptibly raised out of the water; and the consequence is, that in these cases, the results may be said to agree very nearly with those previously made; that is, within those limits the power necessary to propel the boat, appears to increase as the square of the velocity: and, as might be expected, a similar coincidence takes place in the higher velocities if the standard of comparison be changed; that is, if instead of comparing the resistance at two and a half miles an hour, with the resistance at ten miles an hour, we alter the standard, and compare the resistance at nine miles an hour, with the resistance at ten miles an hour, or any other two consecutive numbers which express the velocity in miles per hour;—supposing the resistance to vary as the square of the velocity. For, in these cases, the same cross section of the boat, or very nearly the same cross section, is acted upon by the fluid. But, if on the contrary, we compare the resistance at two and a half miles an hour with the resistance at ten miles an hour,—on the same supposition, that the resistance increases as the square of the velocity, we find that the rule does not hold good, and that a much less power will be required to draw the boat through the water, than by theory would seem to be necessary; and this is easily accounted for, by the boat's rising out of the water according to the velocity she moves with. Another boat of different form, dimensions, and weight, might, under similar circumstances, have risen much more or much less, out of the water; in either of which cases, the resistance at ten miles an hour, as compared with that at two miles an hour, would have been found very different from the results we obtained. From this, it is evident, that no formulæ founded on the theory of the squares, or any other index of the velocity, can be depended on for calculating the actual power necessary to pull a boat through the water at different velocities, using one standard of comparison, unless the form, dimensions, and weight of the boat be considered, and enter as a function into the calculation.

* See Appendix C.

Those philosophers who contend for the laws as already propounded, have generally assumed that the action of any portion is the same, as if that portion were a distinct one, and completely detached from the rest, and exposed to the fluid in the same angle. Now, we see in every day occurrence, a calm spot, where the contiguous and surrounding objects are agitated by a breeze; and we can no more venture to calculate, with certainty, the impulse of a fluid upon a body immersed in it, in the manner theorists would lead us to do, than we could venture to calculate upon the intensity of the permanently elastic fluid, in the above familiar case, being the same in the calm spot, that it is on surrounding objects. In cases where the angle of resistance is perpendicular to every part of the transverse section of the body immersed—cases which we can imagine, we may venture to calculate in such a manner, without a very erroneous conclusion; but in almost every case of resistance of fluids which we have to do with, the action or resistance of the fluid upon one spot, is modified by the action or resistance of the fluid upon another spot. The latter is deflected, perhaps, and the consequent stream confounds the former. But even setting aside this difficulty, another immediately presents itself to the disciples of the old school; for let any one who has been influenced by the laws formerly promulgated, examine the above tables, and he will at once see the fallacies as to horse power, which they expose. Now, we have had horses doing work, for which they have again and again been pronounced unfit. Upon the proper estimation of horse power, depends, very much, the comparative cost of rail-road and canal conveyance. In the two standard works of Wood and Tredgold on railways, this subject is discussed, and formulæ given for ascertaining the force which a horse can exert at a given velocity; but both appear to be very defective in certain cases, and are founded on a limited number of experiments at low velocities. Mr. Wood supposes the force which a horse can exert, to be equal to $\frac{224}{v}=f$, and that for every velocity above three miles an hour, five per cent should be deducted from the force given by the formulæ. Mr. Tredgold takes the formulæ $m\left(\frac{v-v}{v}\right)=p$, in which he supposes $m=250$ lbs., and v, the greatest velocity which a horse can exert when unloaded. There are objections to both these formulæ, which on another occasion I will notice. It is sufficient now to state, that by Mr. Wood's formulæ, and according to his table, page 458, where he gives a comparison between the effects of horse power when drawing on canals and railways, that it would require one hundred and ninety-three horses to draw four hundred and eighty tons over one mile in a day, at the rate of ten miles an hour, or 2·4 tons over one mile, by one horse. And Mr. Tredgold, in his table, page 169, states that the useful effect which a horse can produce in one day, at the velocity of ten miles an hour, is 6·6 tons. Now the average number of passengers carried in the light boats between Glasgow and Johnston, may be fairly taken at forty-five, or about three tons; and the boats are drawn by two horses, at the full velocity of ten miles an hour, the horses travelling twelve miles a day, at four different intervals of time: this is equivalent to thirty-six tons, drawn over one mile by two horses, or eighteeen tons by one horse each day; and this they are enabled to do without injury, although Mr. Wood states 2·4 tons, and Mr. Tredgold 6·6 tons, as the work of a horse under similar circumstances. All calculations, therefore, which have been hitherto made as to the relative value of canal and rail road conveyance, founded upon these formulæ,—which furnish results so different from practical experience,—are totally fallacious and inaccurate.

As there was no reason to doubt the accuracy of the law, that the resistance increased as the squares of the velocity, where the transverse section immersed remained the same, we were now enabled to come to the conclusion, that the boat emerged so much from the water as to account for the difference shown in the tables, between the power of traction required in experiment, and the calculation of the squares of the velocity. In order, therefore, to determine this matter satisfactorily, it was advisable to make it matter of accurate experiment. The bow of the boat had been observed to rise higher out of the water as we increased the velocity, and it was seen that the boat subsided to its former level, as the velocity decreased. In order to see whether this elevation at the bow, observed by Mr. Gordon, in the course of the experiments, Tables II. III. IV. was not accompanied by a corresponding depression at the stern, Mr. Saxton constructed a pendulum,* which he suspended above the centre part of the floor of the boat. When the boat was started, the pendulum indicated at first a rise at the bow, and a depression of the stern, but in a short time, when the boat was fairly under weigh, the pendulum indicated a more even keel, whilst the rise of the bow out of the water remained the same.† Thus it was satisfactorily proved that the bow emerged first, and the stern emerged immediately afterwards. Hence it was inferred that the surge or wave, being proportionate to the water displaced by the boat, would not increase with the velocity of the boat. This was afterwards proved,—see Table V.

* A pendulum is now used in most of the Scotch canal boats, so as to prevent the boats from heeling, to keep them properly trimmed and thus to save the horses labour.

† This pendulum was afterwards removed, and a spirit level used in its place.

When a whale is harpooned, and swims off at a velocity of twenty-five or thirty miles an hour, it is usual with the whale boats to rise at the bow so much that six feet of the keel may be seen above the surface of the water, and this whilst the line makes an angle of 45° with the horizon, in an opposite direction; it is clear, therefore, that the effect of getting the boat higher out of the water is produced, not by any peculiar mode of traction on the bank of the canal, as a late writer upon rail-roads has said, but by the inability of the boat to divide the same mass of water at a high velocity as it does at a lower speed. And this is a fact which goes to contradict the supposition that it is only in a narrow canal, where the water cannot escape laterally, that a boat will partially rise out of the water; shewing as it does clearly, that even in an open sea the same effect must be produced. The effect will no doubt be modified by different situations.*

It must be evident to all who have observed the way in which bodies, exactly similar, will, at different velocities along the surface of the water, sink or swim, that there is a velocity at which even an iron shot will not sink until it has recoiled from the surface of the water once, or twice, or oftener. And reasoning upon such facts, we are warranted in contending that there is a velocity at which the boat will not penetrate the water.

The degree of emergence of the boat from the water, I obtained as accurately as the limited time and means at my disposal enabled me. On plate III., (the drawing of the experimental boat,) will be seen the positions 1. 2. 3. 4. 5. 6. 7. 8. 9., at which the observers were stationed to determine the rise of the boat. Upon the top of the gunwale of the boat at these places, blocks of wood, an inch and a half thick, were nailed in such manner that they projected three inches over the side. The end of each block was chisseled off quite perpendicular, so that the observer by holding a measuring rod flat against the extreme end, and by raising or depressing the rod,—the edge of it just skimming the water,—was enabled to see the space between the top of the block on the gunwale, and the surface of the water perpendicularly under it. During a trip of the boat, each person took as many observations as he could, and the means of all the observations are noted on Table V.

If the funds at my disposal had been sufficient, I would have constructed a long tube with upright glass cylinders at each end, which would have been graduated, and by means of a stop cock, any fluid in the tube might have been so regulated, that the angle which the boat made in the water at any velocity, might have been ascertained with the greatest accuracy by fixing the tube in the bottom of the boat, in a line with the keel, and, at the same time, measuring the height of the stem out of the water; which is easily done, as there is not the slightest agitation of the water before the bow of the boat, at high velocities.

* The action of this whale boat on the water is exactly the action of a boy's kite in the air.

TABLE V.

Experiments made with "the Grahame and Houston" Passage Boat, on the Paddington Canal, for the purpose of ascertaining the fact of the Boat rising out of the water at high velocities, and the amount thereof. 29*th April*, 1833.

Time of passing each Stake by Chronometer No. 533, taken by Mr. Turnbull.	Interval of Time occupied in passing over the distance of 100 yards between each stake	Velocity in Miles per hour.	Height of bracket on the gunnel of boat above water, surface in inches, 8·7 feet from the bow. Starboard Mr. Bourns.	Larboard Mr. Norton.	Height of bracket on the gunnel of boat above water, surface in inches, 26·3 feet from the bow. Starboard Mr. Saxton.	Larboard Mr. Gordon.	Height of bracket on the gunnel of boat above water, surface in inches, 43·11 feet from the bow. Starboard Mr. Carpenter.	Larboard Mr. Baker.	Height of bracket on the gunnel of boat above water, surface in inches, 61·7 feet from the bow. Starboard Mr. Gardner.	Larboard Mr. Gardner.	Observations.
			24	24	19	20	18	18·25	18·75	18·5	Boat empty.
			23	21·5	18·5	17·75	17·5	16	18	16·5	With 11 Passengers.
			21·75	20·5	17·5	16·5	16·25	14·75	16·5	15·5	11 Passengers and 12 cwt.
			20·5	19·25	16·25	15·5	15·5	14·25	15·25	14	11 ditto, and 24 cwt.
			19·5	18·25	15·25	14·5	14·5	12·75	14·25	12·8	11 ditto, and 36 cwt.
			19	17·5	14·5	14	13·5	12·25	13.25	12	11 ditto, and 44 cwt.
h. m. sec.			17·5	17	14	13·75	13·5	12·5	13·7	12·8	10 ditto, and 47 cwt.
2 53 41											
2 54 19	38	5·383	16	16·5	13·5	13·8	13·75	13·75	12·75	12·2	
2 54 56	37	5·528	16·3	16·25	13·25	13·8	13·25	14	13	12	10 Passengers and 47 cwt.
2 56 45	49	4·174	17·5	17	13·25	14	13·4	14·2	12·8	11·75	
			Observation taken at stem by Mr. Bourns.								
3 16 50·5			23·75 at rest		13·5	14·5					
17 9·5	19	10·766	26·7		12·75	14·75	12·5	12·4	12·9	12·4	
17 29	19·5	10·490	27·3		12·75	14	12·25	12·75	13·9	12·25	
17 49	20	10·227	26·87		13·75	14.5	12·25	13·25	12·9	12·25	Ditto ditto
18 10	21	9·740	26·87		13	14·75	12·5	12·75	12·9	12·5	
28 0			23.75 at rest								
29 25·5	1′ 25″·5	2·392	23·75		13·75	14·5	12·6	13·7	12·9	12·75	
30 53	1 27·5	2·337	23·75		13·5	14	12·5	13·5	12·9	12·9	
32 14·5	1 21·5	2·509	23·75		13·25	14·75	12·6	13·1	12·75	12·9	Ditto ditto
33 39	1 24·5	2·420	23·75		13·25	14·7	12·75	13·1	12·75	13	
51 48			26·25 at rest			15.5					
52 7·5	19·5	10·490	28·87		13·9	17·1	13·9	13·7	14	15	
52 26·5	19	10·766	29·3		13·7	17	13·7	14	13·75	14·75	10 Passengers and 23 cwt.
52 46·5	20	10·227	29·4		13·7	17·5	13·1	14	14	15	
53 8	21·5	9·514	29·2		13·75	17·5	13·5	14	14	15·1	
4 4 13·5											
4 47	33·5	6·106	27·25		15·1	16·5	14·7	15·1	14·9	14·7	
5 20	33	6·198	27·78		15·3	16	14·7	15·25	14	14·75	Ditto ditto
5 52	32	6·392	27·4		14·8	16·75	14·25	15·4	14·5	14·75	
6 27	35	5·844	27		14·9	16·6	15	15·2	14.7	14·7	
16 51											
18 11·5	1′ 20″·5	2·541	26·25		15·25	16·75	14·4	16	15	15·5	
19 38	1 26·5	2·376	26·25		15·1	16	14·6	17·1	15·1	14·1	Ditto ditto
20 46	1 8	3·008	26·25		15·75	16	14·6	17·1	15·1	15	
22 1	1 15	2·727	26·25		15·75	16	14·5	17·25	15·5	15·25	
41 18·5			28·25 at rest						17·5	17	Boat at rest.
41 37	18·5	11·057	30·78		16·75	18·25	15·9	16.1	16·75	16·5	
41 55·5	18·5	11·057	31		16·5	18·5	15·9	16·1	16·7	16·7	10 Passengers and 300 lbs.
42 15·5	20	10·227	31		16·1	18·25	16·6	16	16·5	17	
42 37·5	22	9·297	30·9		16·5	18·5	15·9	16·5	16·6	17·1	
51 7											
51 38	31	6·598	29·6		17·5	18·5	16	17·1	17	16	
52 5	27	7·576	30·9		16·5	18·7	16·1	17·2	17	17·25	Ditto ditto
52 31	26	7·867	29·7		16·5	18·5	16·2	16·7	17	17·2	
53 1	30	6·818	29·5		16·5	18·5	16·5	17·2	16·25	16·75	
59 9											
5 0 23	1 14	2·764	28·25		17	18·5	16·2	17·5	17·2	17·4	
1 36·5	1 13·5	2·783	28·25		16·75	18·7	16·2	17·4	17	17·5	Ditto ditto
2 45·5	1 9	2·964	28·25		16·7	18·2	16·25	17·5	16·9	17·75	
3 58·5	1 13	2·802	28·25		16·9	18·2	16·2	17·4	16·9	17·5	

The Boat at rest.

In consequence of an accident, the force of traction in these experiments was not taken.

From this Table it will be seen, that the obliquity occasioned by the line of the horses' traction must enter as a function into any calculation of power necessary to impel a boat; and that the traction shown to be necessary in the foregoing tables ought to be stated at a lower figure, in consequence of the heeling of the boat to the side on which the horses pull.

To determine the rise of the wave upon the banks, four stakes were placed, as on the previous occasions, at intervals of one hundred yards, upon the banks, and at the edge of the canal. The water level was carefully marked on each. These stakes were lettered A, B, C, D, E: these were divided into inches, and placed in the water so as to have the zero point exactly even with the surface of the water when at rest: behind each of these, another stake was placed in a line crossing the canal at right angles, to enable the person who called out the time in the boat, to observe with more accuracy, the exact instant that a particular part of the boat crossed the line of collimation. An observer stood at each post, and noted down the exact height to which the wave or surge rose above the level, when the boat passed, with different degrees of velocity; a cross section of the canal was taken at each line of stakes, drawings of which are given at Plate II. On the 3rd day of April, the first set of these experiments (Table VI.) were made; there was scarcely a breath of wind, and the water was perfectly still. Mr. Holland, the Surveyor of the Grand Junction Canal, stood near the stern of the boat in a line with the bulk-head of the after cabin, and called out "*time*" at the moment of passing the line of each set of stakes. Mr. Whitwell and Mr. Dundas observed the chronometers, and noted the exact time when the signals were given; and the observers on the shore, Messrs. Baker, Bourns, Oborne, and Turnbull, marked the height of surge.

TABLE VI.

Experiments made on the Paddington Canal with the "Grahame and Houston" Passage Boat—twelve passengers for the purpose of ascertaining the height of the wave at different velocities. *3rd April,* 1833.

No.	Time observed.	Spaces passed over.		Miles per hour.	Height of surge in inches.	Observers.	Observations.
	° ′ ″	Mean Time.	Yards.				
1	1 6 45	17½	100	11·9	·5	Baker.	
	1 7 2·5	16	100	12·92	4·5	Bourns.	Commencing at Bridge No.
	1 7 18·5	17	100	12·10	4·0	Oborne.	6, and proceeding westwards.
	1 7 35·5	18½	100	11.2	3·0	Turnbull.	
	1 7 54·5						
				12·07	3·8*		
2	1 31 13				2·75	Davis.	
	1 31 30	17	100	12·1	3·25	Bourns.	Commencing 400 yards
	1 31 47	17	100	12·1	4·50	Turnbull.	west of bridge, and proceed-
	1 32 5	18	100	11·4	3·00	Oborne.	ing eastwards.
	1 32 31	26	100	7·9	0·5	Baker.	
				11·87	3·58†		
3	1 42 16				2·5	Davis.	
	1 42 37	21	100	9·8	2·75	Bourns.	
	1 42 57	20	100	10·3	4·00	Turnbull.	Ditto.
	1 43 17	20	100	10·2	3·00	Oborne.	
	1 43 41	24	100	8·6	1·00	Baker.	
				10·1	3·25†		
4	2 21 0				2·5	Davis.	
	2 21 22	22	100	9·3	3·0	Bourns.	
	2 21 44	22	100	9·3	4·0	Turnbull.	Ditto.
	2 22 5	21	100	9·8	3·0	Oborne.	
	2 22 32·5	27	100	7·6	2·0	Baker.	
				9·5	3·3†		
5	2 32 41				0·5	Davis.	
	2 33 18	37		5·55	1·0	Turnbull.	
	2 33 54	36		5·7	9·0	Bourns.	Ditto.
	2 34 28	34		6·1	2·5	Oborne.	
	2 35 8	40		5·15	1·25	Baker.	
				5·78	4·17†		

* Mean of three last experiments.

† Mean of three intermediate experiments.

The second series of experiments on the wave, (Table VII.) were made upon the sixth of April, in the presence of Mr. Telford, Mr. Babbage, Captain Basil Hall, R.N., General Wilson, Mr. Gill, and several other scientific and professional gentlemen. The arrangements were in other respects the same as upon the previous day. The height of the wave being taken by the gentlemen whose names are mentioned on the table. The signals of passing the stakes were given by Mr. Holland, and the times of the chronometers were observed by Mr. Whitwell, Mr. Gardner, and Mr. Dundas.

TABLE VII.

Experiments made on the Paddington Canal, with the " Grahame and Houston" Iron Passage Boat, for the purpose of ascertaining the height of Wave at different velocities. 6th April, 1833.

No. of Experiments.	Time by the Chron. No. 533. Dundas.	Time by the Chron. No. 385. Whitwell.	Difference of Time from No. 533.	Difference of Time No. 383.	Mean Time of both Chron.	Space passed over in yards.	Velocity in miles per hour.	Height of wave in inches.	Observers.	Observations.
	h. m. s.	h. m. s.								
1	12 33 32	12 33 30·5								
	12 33 48	12 33 47	16·5	16·5	16·5	100	12·0	5	Bourns.	With 27 Passengers.
	12 34 5	12 34 3·5	16·5	16·5	16·5	100	12·3	4	Wilson.	
	12 34 22·5	12 34 21	17·5	17·5	17·5	100	12·0	3·75	Oborne.	
	12 34 41·5	12 34 40	19·0	19·0	19·0	100	10·8	3·25	Turnbull.	
			69·5	69·5	69·5	400	11·77	4	means.	
2	12 46 42	12 46 41								
	12 47 00	12 46 57·5	18	16·5	17·25	100	11·4	4·75	Bourns.	With 27 Pas engers.
	12 47 17	12 47 16	17	18·5	17·75	100	12·1	4·75	Wilson.	
	12 47 36	12 47 34·5	19	18·5	18·75	100	10·8	3·75	Oborne.	
	12 47 55·5	12 47 54	19·5	19·5	19·5	100	10·5	3·25	Turnbull.	
			73·5	73	73·25	400	11·16	4·12	means.	
3	1 1 19	1 1 17·5								
	1 1 41·5	1 1 40	22·5	22·5	22·5	100	9·1	5	Bourns.	With 23 Passengers.
	1 2 4	1 2 2	22·5	22	22·25	100	9·1	4·5	Wilson.	
	1 2 26	1 2 24·5	22·0	22·5	22·25	100	9·3	3·75	Oborne.	
	1 2 49·5	1 2 48	23·5	23·5	23·5	100	8·7	3·25	Turnbull.	
			90·5	90·5	90·5	400	9·04	4·12	means.	
4	1 43 37	1 43 35								
	1 43 57	1 43 55	20	20	20	100	10·2	6·5	Bourns.	With 46 Passengers.
	1 44 15·5	1 44 13·5	18·5	18·5	18·5	100	11·1	6·0	Wilson.	
	1 44 34	1 44 32	18·5	18·5	18·5	100	11·1	5·25	Oborne.	
	1 44 54·5	1 44 52	20·5	20	20·25	100	10·0	3·75	Turnbull.	
			77·5	77	77·25	400	10·59	5·37	means.	
5	1 52 18	1 52 15·5								
	1 52 40·5	1 52 38·5	22·5	23	22·75	100	9·1	7·0	Bourns.	With 46 Passengers.
	1 52 3	1 53 1	22·5	22·5	22.5	100	9·1	5·5	Wilson.	
	1 53 24·5	1 53 22·5	21·5	21·5	21·5	100	9·5	5·0	Oborne.	
	1 53 46·5	1 53 44·5	22	22	22·0	100	9·3	4·5	Turnbull.	
			88·5	89	88·755	400	9·21	5·5	means.	

The times of the above experiments were also observed by Mr. Gardner, with a pocket chronometer. His observations, in no instance, differed more than half a second from those given in the Table.

A surge upon the canal embankments is no doubt to be avoided. Still, it is but fair to say, much depends upon the slope and nature of the bank. I must, however, state, that no very satisfactory observation upon the surge, merely occasioned by the boat, can be obtained upon the edge of the canal. The action of the water in motion upon the bottom and sides of the canal is dependent upon the amount of friction. Here the resistance appears correctly stated to be nearly proportioned to the squares of the velocity. The friction, nevertheless, varies according as the extent of surface of the water in contact with the bottom and sides, is more or less, when compared with the amount and depth of water. For instance, the surface of a deep and rapid stream may be smooth, whilst the bottom is rough, and yet the surface of a shallow and rapid stream, with a more uniformly smooth bottom, will be agitated. In a canal it is distinctly seen, that whenever the banks are closed up almost perpendicularly, as at docks, bridges, &c. where the width is not contracted, there is little or no surge; but when the inclination of the banks are very oblique, the wave is immensely increased, both in size and in its distinctive properties; acting like a breaker upon the sea beach or on a bar. The slope of the banks of the Paddington Canal, particularly on the towing-path side, is therefore the worst possible for boats proceeding at high velocities; but where the banks are formed in a different manner, as on the Ardrossan Canal, we are still enabled to reconcile the results obtained on these experiments, with the facts stated, that "the quick passage boat makes little or no surge." I do not, however, shelter myself under this peculiar case of the malformation of the banks of the Paddington Canal, to avoid the force of an assertion of those interested in railway speculations, "that the wave which followed the boat washed the banks and displaced the gravel just as a tide on a shore, and that therefore nine miles an hour is too great a speed to be attempted if the canal banks are to be regarded." *(See Appendix D.)*

Had those who made this assertion stopped to examine the cause scientifically, they would have attributed the effect to the slope of the bank, and *not* to the velocity of the boat. That it does not arise from the boat has been shown already. That it is from the slope might have been deduced, by their professed science, from those laws which led Mr. Smeaton to give to the Eddystone Lighthouse such a judicious curve, as to throw the foaming billow which buffets this monument of his fame, far above the height of the surrounding seas. His object in so doing was obvious; but the very same reason which induced him to give it such a curve, would prevent a canal engineer from forming his banks so that the breaker which follows the moving body should wash the gravel on it into the canal. By a vertical bank simply, this difficulty would be in a great measure avoided; but in cases where the natural soil is tender, they should be lined with a course of stone, a foot high. In some canals the rushes which grow on the banks break the force, which would have a tendency to injure them; but the obvious method is the one above suggested.

There is no branch of practical science, which has involved in its current operations so much money, and there is certainly none, of which the laws are more intricate and undefined. We have already seen the results of these imperfectly understood laws, and we must now turn our attention to that method by which we can evade them, or get partially out of their control, as we do when the boat is caused to rise out of the water.

To arrive at this method, and to determine the required construction, differing widely as it must from that which has been made to contend with the old law, will be a very interesting effort.

It is not necessary to advert to all the instances where variation of the old law has attended variation of the boat's form, nor will an historical summary of the experiments conducted by various philosophers be expected here. I shall, therefore, briefly mention the line of discovery by which a well known law has been brought into successful and lucrative application.

Fourteen years ago Mr. Robison, Secretary to the Royal Society of Edinburgh, had been informed by Mr. Perkins, that upon one of the rivers of the United States, he had observed a barge (length sixty feet, and ten feet of beam) loaded with hay, so acted on by a strong wind, that the barge appeared to rise about three feet above her water line, and to skim with very great velocity upon the surface of the water. Mr. Robison, in consequence, made some experiments two years ago, upon the Forth and Clyde Canal, and the results of these experiments will very shortly appear in the Transactions of the Royal Society of Edinburgh. They were made by fixing a long spar upon, and across, the cut-water of a steam-boat. The spar was nicely balanced upon the cut-water. To each end of this spar, the model of a boat was attached. One model being sharp at the bow and bottom, and the other model being perfectly flat bottomed. It was found that at the velocities, under six miles an hour, the sharp-shaped boat was more easily drawn through the water; but that at all velocities above six miles an hour, the flat-bottomed boat surpassed the sharp boat. This difference in the power required, was ascertained by Mr. Robison in pounds, and will constitute a very interesting paper when published.

Mr. Fairbairn had been previously engaged by Mr. Grahame in the extensive course of experiments, which are recorded in his "Remarks on Canal Navigation, illustrative of the advantages of the use of steam."

But previous to either, namely, in the spring of 1830, Mr. Houston was induced to attempt a light gig-shaped boat, already mentioned in page 3 of this paper. And now, not only are passage-boats increasing in number and prosperity, but luggage-boats are in many instances established at these higher speeds. The London, Leith, Edinburgh, and Glasgow Shipping Company, despatch their boats with goods and passengers every lawful evening, from Edinburgh for Glasgow, at six o'clock.

Fares for passengers to Glasgow—First Cabin, 5s.; Second Cabin, 3s. 6d. intermediate distances, moderate.

" The Company lately commenced running at an increased rate of speed, an additional Night Passage Boat every lawful evening, at nine o'clock, arriving at Glasgow the following morning, about eight o'clock, when the goods are immediately in progress of delivery.

" Thus affording to passengers a conveyance (very superior in point of comfort) several hours after the day Glasgow coaches are despatched, at one half of the fares at present charged by them. The rate, for packages and parcels is less than half of the charge by the coaches, and for bales and boxes, or other heavy goods, is at a rate, less than the half charged by the vans.

" Packages and parcels under two stones, only 6d.; ditto, four stones, only 9d. The Company's Luggage Boats are also now despatched daily, carrying goods at the cheapest rates."

Plate IV. is a drawing of a passage boat now running on the Monkland Canal, and Plate V. is a drawing of one now running on the Forth and Clyde Canal.

On Plate VI. is a drawing of one of the passage and luggage boats.

Boats similar in shape and quality to the Scotch passage-boats are now introduced in the Lancaster and Preston Canal,* and must shortly become general upon all canals. (*See* Appendix F.)

Plate VII. are the transverse sections of a part of the Kennet and Avon Canal.

In the conviction that these banks were so formed that no possible injury could arise to them from the passage of the boat, at the required velocities, the committee of that Canal Company have been induced to encourage a carrier to employ the boat " Grahame and Houstoun," for the present, between Bath and Bradford, a distance of ten miles on one level, as a mode of conveying passengers

* According to the information given by Mr. Grahame, of Glasgow, to the Institution of Civil Engineers on the last evening of their meeting, (11th of June) these boats now accomplish the distance of thirty-one miles in three hours, and half an hour more for stoppages. This they had done for more than two months. The actual *cost* for conveying each boat is one shilling per boat per mile. By water the distance is thirty-one miles, by land the distance is twenty-two miles. But, notwithstanding the greater distance, so highly is the canal conveyance esteemed by passengers, that coach contractors have had to reduce their fares considerably.

and light goods, with a view to extend the plan to greater distances. The horses are changed once in this stage, which is about the average distance at which they are changed on the Scotch and the Lancaster canals, and very little less than the distance at which the horses are changed on the turnpike roads by all the fast-going coaches in England.

With the history of the past then as our warrant, we may, in regard to canal navigation, anticipate the future, in the probability of an improved canal conveyance between London and Birmingham and the North West of England.

One of the greatest advantages, in a commercial point of view, next to cheap and expeditious means of travelling between two great towns, is that of having frequent opportunities of doing so in the course of the day. If the number of omnibuses, which now ply singly through London, from Paddington to the Bank, at almost every five minutes in the day, were collected in one train and started at intervals of every three or four hours, as the trains drawn by locomotive carriages between Liverpool and Manchester, the accommodation they would then afford to the public, would bear no proportion to that which is gained by their travelling singly and at short intervals between each. On the same principle the accommodation which is now given to the public by the coaches which run between London and Birmingham, is not so great as if the same number were to start at different hours in the day, instead of the day coaches all starting at nearly the same hour in the morning, and the night coaches at nearly the same hour in the evening. Should a rail-road ever be made between these towns, this accommodation to the public would be still lessened, for one train of carriages, or at most two, would take nearly all the passengers that now travel this road by the stage coaches; and instead of even a short interval, as at present, between the departure of the coaches, travellers must all collect at one point, at one moment of time, or lose an opportunity which may not occur for the rest of the day; for it would appear that locomotive carriages cannot run on railways with economy, (that is, pay the interest of the outlay on the railway and the contingent expenses, connected with it,) unless they take a large train of waggons with them at the same time. If this were not the case, there can be no doubt that the inconveniences to which travellers are subject, and which have been so much complained of on the Liverpool and Manchester railway by crowding together upwards of a hundred passengers at one time, would have long ere this been remedied by running light locomotive engines, drawing one or two carriages, with twenty or thirty passengers, and starting at every hour in the day; but, instead of this, I believe the engines have constantly been increased in weight and power since the opening of the railway, and rendered capable of taking a larger train of waggons at each trip.

By proper and judicious arrangements, and boats constructed on proper principles, I have no doubt whatever that a lucrative business in the transport of passengers between London and Birmingham, and the North West, might be established on the canals, even in their present state, besides affording to the public the great advantage of numerous opportunities of departure and arrival in the course of the day.

For this purpose, boats much *smaller, lighter, and of a flatter* and *rounder build than those* employed on the *Paisley Canal*, should be constructed to carry twenty passengers, and fitted up something similar to the city omnibuses, with cushions, windows, &c., but with the addition of a narrow table in the centre, and having one part set off as a state cabin capable of accommodating eight passengers; these boats may be drawn, with the greatest ease, ten miles an hour by one horse.

Boats of this description would cost about 120*l.* each; and supposing one to start from London, and one from Birmingham, at every two hours—the first to start at six in the morning, the last at six in the evening,—fourteen boats would be required for actual work, and say six spare ones, in all twenty—the cost of which would not exceed 2,400*l.*

If we estimate each boat to take an average of only four cabin and ten steerage passengers, and a quarter of a ton of parcels or light goods, the total weight will not exceed one and a quarter ton; and supposing each cabin passenger to pay one pound, each steerage passenger eight shillings, and parcels three pence per pound, for the whole distance, a very considerable profit might be realized, and the public much benefited. In order to save time in passing the locks, and also to prevent the waste of water, which would otherwise take place, in passing so light a boat through them, inclined planes should be made at each lock, over which the boats might be taken on a truck with safety and expedition by the horse employed to haul them on the canal; the expense of these inclined planes would be very trifling, and they should be carried into effect by the respective Canal Companies in the first instance, who might afterwards repay themselves by a small charge on the passage of each boat. The time in which a boat might make the journey between London and Birmingham would probably not exceed twenty hours, allowing fourteen hours for travelling, and six hours for changing the horses and passing the inclined planes, and even this time might be much lessened by the Canal Companies forming a towing path, four feet wide, (which would be quite sufficient) on the opposite side of the canal from that which the horses travel in hauling the heavy boats, and by aking off some awkward bends which now exist on the Grand Junction Canal, by which it would be much improved at a comparative small outlay.

There are two lines of canal navigation from the extremity of the Grand

Junction Canal at Braunston, which now form the great communication diagonally through England, with Birmingham and the North West.

On the northern end of the Oxford Canal, which forms a part of this line, much has already been done in shortening the distance. The banks are faced with stone in the best manner; and in some experiments, made so late as the 4th of July, the committee of that canal, attended by their engineer, Mr. Cubitt, were satisfied that they could sustain no injury from the operation of the boat. (*See* Appendix E.)

The other line, through the Warwick and Napton and Warwick and Birmingham canals, is much shorter, as it respects the communication between London and Birmingham only. The competition, however, excited by rail-road speculations, will no doubt operate to the reduction of distances on all the above-named canals, as well as to a great diminution of the lockage. These lines of reduction are very obvious, and have been surveyed and proved to be capable of execution at an expense infinitely below the *calculated expenditure* of the proposed railways.*

The detail of the application of the fast boats, the probable receipts and expenditure, time of passage, and means of accomplishing it under present circumstances, is, however, not within the line of this treatise. The possibility and capability of doing it is, I think, sufficiently shown, not only on this line, but on many other lines of canal.

But to return to the variations of the old law, which have attended every variation of the boat's form, it will be seen by Table VIII. which is abstracted from the preceding tables, and by some instances from other experiments added thereto, that great importance attaches to the shape of the boat, and also that EACH BOAT EXHIBITS A FEATURE PECULIARLY ITS OWN. So that it is needless to expect to get the measure of resistance, at different velocities, from any general formulæ.

* "The conclusive proof that mile for mile railways cannot compete with canals in the carriage of goods, is drawn from a printed document, issued by the promoters of the London and Birmingham Railways, called Mr. Lecount's 'General Results of the Traffic Returns between London and Birmingham in one Year; also the expenses of carriage by the present means, and by the Railway:' in this he states that 1,125 boats conveyed 124,029½ tons of goods along the canals, a distance of 147 miles, at an expense of 310,073*l.* 15*s.*, and that by the railway they will be conveyed a distance of 112 miles for 290,694*l.* 2*s.* 9¾*d.* It results from this statement, that notwithstanding the distance by the canals is as 147 to 112, or more than *one-fifth* greater than by the railway, the total expenses, as stated by the projectors of the latter, are only *one-fourteenth* part greater, that divided proportionably per mile, they would be on the railway 2,590*l.*, and on the canals 2,109*l.* Of that expenditure, taking Mr. Lecount's own estimate of 124,029 tons for the total amount, no less a sum than 173,640*l.*, at the rate of 28*s.* per ton, is paid to the Canal Companies in the shape of tolls; and as it has been fully proved that on the pattern railway, between Liverpool and Manchester, a very small part only of the tolls can be received; a reduction of tolls by the Canal Companies, which self-defence would reduce them to make, would render it impossible for the railway to compete with them."—*Observations on the Comparative Merits of Canals and Railways.* Second Edition, p. 39. Longman and Co., 1832.

It is clear that reduction of distances would operate equally in reducing competition with canals.

TABLE VIII.

Constructed partly from the Experiments of others, and partly from the Experiments detailed above, for the purpose of exhibiting the comparative increments of Power required by different shapes and sizes of Boats.

From Mr. Walker's Experiments.				From Mr. Fairbairn's Experiments.				From the Society of Naval Architecture's Experiments.		From the Foregoing Pages.							
Length of water line immersed . . 24 ft. 9 in. Breadth of do. do. . . 7 ft. 0 in. Depth of immersion, exclusive of keel . . 1 ft. 2 in. Weight of boat Do. of cargo .		Length of water line immersed . . 18 ft. 6 in. Breadth of do. do. . . 6 ft. 0 in. Depth of immersion, exclusive of keel . . 1 ft. 9 in. A full built boat. Weight of boat Do. of cargo, 2 tons.		Weight of boat and cargo, 116 cwt. 1 qr. 14 lb.		Weight of boat and cargo, 108 cwt. 2 qr. 24 lb.		"The models were of various lengths, but all one foot broad and one deep, and either sunk considerably under the surface and held there by bars, attached to a floating body, or sunk till their upper surfaces were just level with the water." Surface 40 square feet.		Diving bell, boat model.		Copper boat "Ardrossan," See Table I.		Copper boat "Grahame," See Table I.		Large iron boat, "Grahame and Houston." See Tables II. III. IV.	
Velocity in miles per hour.	Traction in lbs.	Velocity in miles per hour.	Traction in lbs.	Velocity in miles per hour.	Traction in lbs.	Velocity in miles per hour.	Traction in lbs.	Velocity in *nautical miles* per hour.	Traction in lbs.	Velocity in miles per hour.	Traction in lbs.	Velocity in miles per hour.	Traction in lbs.	Velocity in miles per hour.	Traction in lbs.	Velocity in miles per hour.	Traction in lbs.
1·92	11·00	2·51	9·23	..	..	..	..	1	0·56	..	..	..	..	2·09	·46	2·21	23·5
2·22	13·08	2·53	10·10	..	..	..	..	2	1·99	..	..	..	..	2·89	1·	2·51	25·24
2·60	18·10	..	..	..	..	..	..	..	..	..	..	..	..	2·92	1·71	3·13	29·98
..	..	3·83	27·26	..	..	..	..	..	..	..	..	..	..	3·29	1·71	3·61	46·5
..	..	3·87	28·07	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4·04	4·72	4·50	43·08	4·17	44·20	4·83	82	4	6·64	..	..	..	..	..	..	4·23	45·24
4·138	4·95	4·55	49·34	..	..	..	..	..	..	..	..	..	..	..	..	4·95	61·21
..	..	..	..	..	..	..	..	..	..	5·11	1·71	..	..	5·23	3·15	5·61	141.44
..	..	..	..	..	..	..	..	..	..	5·53	1·71	..	..	5·39	3·15	5·68	150
..	..	..	..	..	..	..	..	..	..	5·68	4·35	..	..	5·69	3·15	5·85	154
..	..	..	..	..	..	..	..	..	..	5·68	7·26	..	..	..	..	5·917	168
..	..	..	..	6·25	111·25	6·22	205·3	6	12·83	6·39	7·26	..	..	..	..	6·99	154
..	..	..	..	..	..	..	..	..	..	6·81	7·26	..	..	..	..	..	..
..	..	..	..	7·57	204·92	7·28	378·5	..	..	..	..	7·30	1·71	7·19	5·81	7·420	116·6
..	..	..	..	7·65	202·35	..	..	..	..	..	..	7·86	1·71	7·52	5·81	7·72	148·26
..	..	..	..	..	..	..	..	..	..	..	..	7·86	1·71	..	..	7·89	152·15
..	..	..	..	8·02	254·85	..	..	8	19·85	..	..	..	..	..	..	8·02	164
..	..	..	..	8·34	313	..	..	..	..	..	..	..	..	..	..	8·12	140·56
..	..	..	..	8·64	268·25	..	..	..	..	..	..	..	..	..	..	8·25	190
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8·76	180·85
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8·92	191·73
..	..	..	..	..	..	..	..	..	..	..	..	..	..	9·60	8·50	9·44	232·73
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10·03	287.85
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10·38	285·15
..	..	..	..	..	..	11·11	420	..	..	..	..	11·36	3·15	11·18	9·86	11·07	294·1
..	..	..	..	..	..	..	..	..	..	..	..	11·36	3·15	11·92	11·21	11·16	287·5
..	..	..	..	12·32	410	12·16	446	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	12·50	439·3	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	13·36	12·61	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	14·61	14·02	..	..

The facts detailed in the foregoing paper, so completely abrogate the laws by which the ship-builder has been regulated, at least, as far as regards canal and steam navigation, that it would be hazardous to state upon these limited experiments what is the best form of boats. So far as I have gone, I fear not the result of investigation, even by the most determined opponent that prejudice may enlist on its side. But where investigation so strongly shows the ignorance which still surrounds the object, it may be well in the mean time not to venture any speculations upon it. With this view the tables have been so constructed, that readers may examine them in various lights, and speculate for themselves.

There are, nevertheless, one or two thoughts which may be ventured before the scientific world. The subject naturally divides itself into two parts: one division will be the considerations for the shape of a canal boat, drawn by an oblique action, as by horses, and the other division is the consideration of the shape of a boat to be forced through the water either by a cord in the direct line of navigation, or by a power in the boat itself.

With regard to the former, viz. the construction of a boat which horses on the bank are to haul. The obliquity of the keel with the line of traction, or line of motion, is not only to be considered, but there is a certain heeling over of the boat (see Table V.) which indicates a loss of the horse's power, and which must be obviated—and it can, perhaps, best be lessened by making the point of traction lower down than the timber head at present used.

When the horses pull obliquely, as they must, it is requisite to set the helm in such manner, that the boat herself assumes an oblique direction, and thus she does not meet the resisting fluid with an equal presentation of each bow. If the horses draw on the larboard side, more of the larboard side of the boat is presented to the water, and less of the starboard side, and be her original construction ever so perfect, she must contend against this peculiarity in horse traction, and hence a loss of power. Whether a keel which could be set obliquely in either direction of the boat might remedy this, I cannot venture to affirm, but whether or not, certainly this difficulty can be obviated by the adoption of steam power.

We are thus brought to the consideration of a boat with the line of traction or line of power in exactly the same direction as the boat's course requires to be.

It has often been asserted, that such advantages as we contend arise from the boat's emergence from the water at high velocities, have never been attained by boats with a power in them—for instance, by such as a row-boat or a steam-boat. With regard to the first of these, the row-boat, we can venture a sufficient reason for such having hitherto been a just remark. When the boatman is rowing his boat, with his face to the stern, by which position he is enabled to bring all the muscles of his legs to his aid, the antagonist muscles, flexors, and extensors, are so caused to balance or counteract each other, that his body is for a part of the stroke, rested, not on the seat of the boat, but suspended, as it were, by a muscular rigidity, very much upon the heels. When, however, the blade of the oar has passed astern of the row-locks, and the intensity of muscular force is relaxed, the boatman seats himself with a thump, which, together with the resistance met with when lifting the oar, invariably dips the bow of the boat deeper, and so prevents her emerging from the water. With a very little attention to a boat when rowed upon smooth water, she may be seen to act in this manner; an oscillation will be perceived to a very considerable extent, occasioned by this shifting of the centre of gravity, not merely in short skiffs, but in the longest wherrys or gallies on the Thames, at every stroke of the oars. In the case of steam-boats, it is also clearly to be seen that no attempt has been made to cause an emergence from the water. The improved speed of steamers within twenty years, has its foundation in the improved character of the machinery, and in the elongation and sharpening of the bows, but it has not been in any instance by attempting to draw less water in proportion to her increased velocity.

From the whole data furnished, then, by the above course of experiments, we arrive at the conclusion, that navigation, whether by traction, or by impulsion,—by the oar, or by the paddle, is yet in its infancy. A bold assertion perhaps, considering how long we have held dominion of the deep; but one, notwithstanding, which we hope to see amply verified by general practice, before many years pass over us. Assuredly our boasted triumphs during the past, over the winds and the waves, will bear no proportion to those which yet lie before us. Hitherto the attention of the shipwright has been directed to giving the vessel velocity *through* the water; but when the velocity already gained shall be aided by the advantage of decreased draught, when the vessel is forced *over* the water, safety and comfort will be the alone limit to speed in nautical science. Shall we then, within sight of such important results, strike the sail of the little skiff by which the discovery has been made, and ride quietly at anchor, content to know that there lies within our reach what will bring so much nearer to our shores the commerce of the world? Or shall the enterprise of this great commercial land, at once promptly furnish the means of confirming the accuracy of the above assertion, by a course of experiments, proportionate to the magnitude and importance of the subject, and adequate to bring such improvements into general navigation practice? Time will show, we hope soon, and trust favourably. Little will it say for the science of our country, if there be not a growing aptitude to shake off the *etourderies* of the past, and to improve a science which tends so much to the common good. The steps now taking by some of the canal companies, in order to give premiums for good and quick boats, is worthy of example. And that department of Government which wields our triumphant navy, and to whose spirited conduct we are indebted for so many improvements in the steam marine, will not, we feel convinced, leave this important investigation to the industry and enterprise of individuals alone; but will in the true spirit of their great trust, by a hearty extension of that power which has given to the mariner the ability of steering a direct course over "the mountain wave," enable him also to abridge, with advantage to his country's wealth and strength, the toils and perils of his "home upon the deep."

For more particular information as to the uses of the Pirameter, the reader is referred to a short description of it published by ROAKE and VARTY, Booksellers, 31, Strand.

APPENDIX.

A.

SPECIFICATION *of a Light Iron Passage Boat, such as ply on the Summit Level of the Forth and Clyde Canal, between Port Dundas and Windford, and such as was used in the Experiments detailed in the foregoing paper.*

Extreme length	70 feet.
Ditto breadth	5½

The iron of the very best manufacture.

The body plates in particular must be free from rust, cracks, blisters, and roughness of every description. The whole of the iron must be coated with linseed oil, previous to its being used. And the boat must be built under cover, so that the work may be kept dry until the boat is finished.

Although not shown on the plan, the said boat (plate IV.) has a hollow keel, so as to prevent the lodgment of water beneath the floor, between the ribs. The stem and stern shall consist of bars of iron, six inches in breadth, and a quarter of an inch thick, which are hammered flat at the lower part to the breadth and thickness of the keel-plate, to which they are scarfed and secured with clench rivets.

As stated above, the keel-plates are formed hollow, and consist of hoop iron, six inches in breadth, and one-eighth of an inch in thickness. To which a wood keel of Memel plank fifty feet in length, nine inches in depth, three inches in thickness next the bottom of the boat, and an inch and a half at the lower edge, tapered off to nothing at each end, must be secured to the keel-plates with glands an inch and a half in breadth, and a quarter of an inch thick, sunk flush into the keel, and screwed inside at the distance of three and half inches apart.

The ribs shall consist of T and angle iron, and placed alternately at the distance of twelve inches from each other, and extending from gunwale to gunwale, after being bent to suit the curved form of the vessel, two rows of holes are punched on the flat side of the angle and T ribs to secure the body-plates, and holes at convenient distances are punched through the upright flange to secure the false ribs for the inside lining.

The body plates must consist of the best double-rolled No. 16 sheet-iron, two and a half lb. per superficial foot, and these sheets are in lengths of eight and ten feet. The first range of bottom plates, which join the hollow keel, eight feet in length and twenty-four inches in breadth; the next two ranges on each side which form the bilge, ten feet in length, by twelve inches in breadth, and the range next gunwale, ten feet in length by eighteen inches in breadth. Particular attention is requisite, both with the view to the strength and appearance of the boat, that the whole of the body-plates be run in fair sheer lines from stem to stern, and that the lower edge of each succeeding length or range of plates cover the upper edge of their accompanying ones three quarters of an inch, so that the boat in every respect may have the appearance of being clencher built.

The butts, or end joints of the plates, must be kept smooth, and meet on the centre of the T rib, and the joints of each succeeding plate be so shifted as to meet on the T rib nearest the centre of its accompanying ones. It must, however, be expressly understood, that previous to any of the plates being rivetted, a thin stripe of cotton cloth, dipped in white-lead paint, be put in between the overlaps of the edge joint, and between the ribs and the end joints, so as to prevent leakage and corrosion. The whole end and edge joints must be secured with countersunk rivets, made from a three-sixteenth of an inch bore, placed at the distance of three-fourths of an inch from centre to centre, and made from the best charcoal rivet iron; the rivets, except those for securing the end joints, must be placed two inches distant from each other, and the whole, as stated above, be countersunk, and kept as smooth as possible.

Plates, six inches in breadth and one-eighth of an inch in thickness, to be placed on each side along the bilge, over the body-plates, where they are most exposed to injury when taking on board and landing passengers, which will extend from the round of the entry, at the bow, to the commencement of the run or exit, at the stern; and is secured to the ribs and body-plates with countersunk rivets, placed at the distance of three inches apart; but before they are secured, both the bilge-plates and body-plates must be properly coated with white-lead paint, and a ply of sheathing dipped in the same, put in between.

One and a quarter inch of angle bars extend from stem to stern, to form the gunwale, to which welts or wood mouldings are secured; and another, of the same dimensions, to be placed seven inches below the gunwale, to which the wood-belting, three inches thick, and four inches deep round off, is to be secured.

The boat is framed and moulded, and in every respect formed exactly and agreeably to the plan, and the work must be done in a substantial and workmanlike manner.

SPECIFICATION *of the Carpenter and Joiner Work of such a Light Iron Canal Passage Boat.*

The length of the boat as specified at seventy feet in length, five feet six inches in breadth, and two feet six inches in depth. It is divided in the following manner, viz.

Fore deck	4 feet in length.
Fore sheets	According to the number of the travellers intended for.
Space for steerage cabin and principal cabin, &c. .	
After sheets	
After deck	4 feet.

The false ribs for securing the inside lining consist of willow timber, one inch in breadth, and seven-eighths of an inch in deepness, which must be free from knots and shakes, so that they may bend easily after being stoved to the curved form of the boat, to which they are secured with nails, rivetted to the upright flange of the ribs.

The sea-crofts, fore and aft, must extend from the stem and stern to the end of the cabins, and be four inches in breadth, and two inches in thickness, of best Memel plank, which is kept flush with the gunwale inside, and secured with three-eighths of an inch rivets, one throughout each rib.

Two timber heads on each side, near the bow and stern, are placed in the most convenient situation for mooring the boat, and secured with glands fixed with clenched rivets, so that the timber heads may be taken out and replaced when found necessary; to consist of solid oak timber, five inches in breadth, two inches thick, one foot in length below the gunwale, and seven inches above.

The beams which support the deck fore and aft, consist of oak plank two inches thick, three inches deep in the centre, and two inches deep at each end, with a curve of half an inch to the foot in length; and they are secured with a sheet-iron plate to the gunwale, angle iron, and sea-croft.

The gunwale or covering boards should consist of the best Memel fir plank, one inch in thickness, which extends from stem to stern; the cover is secured to the gunwale flange and wele that forms a moulding round the same.

The ends and divisions of the cabins should consist of Memel plank, two and a half inches in breadth, and one and three-fourths inch thick, which will form diagonal frames, for the purpose of strengthening the boat, so as to resist external pressures. The said frames must be lined at the ends of the cabins outside, with the best half-inch American yellow pine plank. The framing in the inside of the cabins may be lined as may be approved of.

The sleepers, for support of the flooring, should be two inches deep, by one and a quarter inch thick, placed and fitted to each alternate rib, and fixed to the upright flange with rivet nails. The flooring should consist of the best yellow pine plank, one inch thick, and not to exceed six inches in breadth, which must be properly cleaned, ploughed, and feathered.

The height of the cabins, from the top of the floor to the lower part of the beams, six feet at the centre, and the height of the sides above the level of the floor will be five feet under the beams, consequently the beams will have a curve of twelve inches.

The standards or stancheons of the sides of the cabins should consist of the best white American oak, one inch thick, and one and a half broad at the gunwale, and one inch in breadth at the top of the cabin, and placed at each alternate rib, to which it is secured, the distance being twenty-four inches from centre to centre. The top gunwale, for the support of the roof, to be made of the best Memel fir or red pine, free of blemish or knots, and extend the whole length of the cabins, two and a half inches deep outsides; the upper edge is bevelled to suit the curve of the beams, and two inches in thickness, mortised to fit the tenure of the standard, having a projection for a bead, and thickness of outside lining.

The beams, as stated above, to have a curve of twelve inches, to consist of the best clean ash timber, an inch and a half in breadth, by one inch in depth, the lower part rounded to a half-circle, and is placed at the distance of two feet from centre to centre, dove-tailed and secured to the gunwale with screw-nails ; and a framing of iron wire gauze, well painted, shall be made to connect them, so that the top may form one solid connected form from end to end.

A stringer extends the whole length of the cabins in the centre to support the roof, which is let in, and bound to the diagonal frames, the upper edge kept flush with the top of the curve, consisting of clean solid white Quebec oak timber, three inches in depth, by an inch and a half thick ; into which, the beams are let nearly in the whole depth, and made exactly for the top covering.

The space outside of the cabin, fore and aft, must be lined from the floor to the gunwale with five-eighths of an inch red pine boards, and seated in the usual form ; the tops seven-eighths of an inch thick, with round supports and cross bearers, with two front rails, two and a half inches in breadth, beaded, and let in flush with the bottom and top of the supports or feet.

In order that the boat may be kept as light as possible in the fittings-up, there should be no inside lining of wood from the floor up, consequently the whole seatings in the cabins must have fronts supported with brackets ; these brackets to be secured to a stringer, fixed to the sides of the boat the whole lengths of the cabin, three inches in breadth, by an inch and a quarter thick, to which the brackets are let in flush, and nailed to it and the floor. The seats in the principal cabin to be sixteen inches in height, so as to allow cushions two inches thick and eighteen inches in breadth ; the back to be one inch lower than the front, which is considered an improvement as a comfortable seat ; the seats in the principal cabin may consist of cane, light wood, or lacing, as may be approved of ; the fronts consisting of the best American yellow pine five-eighths boards. The seats in the steerage, eighteen inches in height, by fourteen inches in breadth, and fixed with brackets in the same manner as the principal cabin, and be seven-eighths of an inch in thickness.

The outside lining between the gunwale and top of the cabins should consist of the best yellow pine half-inch boards, well seasoned, free of knots, sound, and properly cleaned, ploughed, and feathered. The first board will extend the whole length of the cabins, eight inches in breadth, neatly joined to the covering boards, thin fitters being fitted between the standards or stancheons, and laid in white-lead paint, so as to be water-tight, is fixed to the side standards with springs.

The space between the standards being twenty-four inches from centre to centre, it is proposed that light windows or patent gauze wire shall be placed in every alternate space, so as the passengers may have a view of the country without being under the necessity of removing to the outside. These windows and frames should be made as light as possible, and made to slide or fold, as may be considered most convenient.

The inside lining, from the seats up, and between the windows, should consist of oil-cloth, fixed and finished with beads and facings.

The top or cover of the cabins to consist of oil-cloth, which must be perfectly water-tight, and fixed to the beams, top gunwales, and ends of the cabin, with a moulding. It will be necessary to have a thin sheet of plate-iron for the funnels, so as to prevent any danger from the heat of the stoves during the winter.

The outside doors should consist of red pine plank, one inch and a quarter thick, bound and pannelled, to be hung with neat light bats and bands, have good five-inch rimmed locks brass mounted, to open out in two halves, and to have small brass slip bolts at top and bottom. The doors in the divisions to have check locks, and hung with five-inch edge hinges.

The inside doors should consist of the best yellow pine plank, one and one-eighth inch thick, and twenty-two inches in breadth, and finished with facings.

That the whole of the inside, previous to the joiner work being commenced, should have two coats of good lead colour paint, and the whole of the iron-work on the outside, as well as the wood-work in the outside, and inside, should have three coats of paint of different colours, and finished in a sufficient and workmanlike manner.

APPENDIX B.

Dynamometer or Pirameter, invented and used by John Macneill, Civil Engineer, described in the foregoing pages.

Mr. TELFORD, in his report to the Parliamentary Commissioners of the Holyhead and Liverpool Roads, speaking of this instrument, states, I consider Mr. Macneill's invention for practical purposes on a large scale, one of the most valuable that has been lately given to the public.

SIR HENRY PARNELL, whose zeal and practical experience in all that regards roads are well known, has repeatedly examined, and personally attended to the trial of the instrument over a great extent and variety of roads, and has given his full approbation of its practical utility and public advantage, as will be seen by reference to his forthcoming work on Roads.

Mr. BABBAGE, the Lucasian professor of mathematics in the university of Cambridge, in his valuable and well known work on the Economy of Machinery and Manufactures, in considering the injury which roads sustain from various causes, has also noticed the utility of this instrument.

APPENDIX C.

Account of Four Experiments made by Mr. H. R. Palmer, Civil Engineer, submitted by him to the Institution of Civil Engineers in April, 1833.

EXPERIMENT I.

Empty barge, weight 6½ tons,—fraction of the force to the whole effect $\frac{1}{205}$,—wind in favour.

Tractive force employed.	No. of Stakes.	Time.	Time between the Stakes.	Velocity per hour in miles.
72 lbs.	1	0·29″	29″	3·104
72	2	1·7	28	3·214
72	3	1·34	27	3·333
72	4	2·00	26	3·461
72	5	2·24	24	3·750
72	6	2·49	25	3·600
72	7	3·13	24	3·750
72	8	3·39	26	3·461
72	9	4·3	24	3·750
72	10	4·28	25	3·660
72	11	4·54	25	3·600
72	12	5·15	22	4·090
72	13	5·41	26	3·461

EXPERIMENT II.

Empty barge, &c. as above,—against wind.

Tractive force employed.	No. of Stakes.	Time.	Time between the Stakes.	Velocity per hour in miles.
72 lbs.	12	0·33″	33″	2·727
72	11	1·2	29	3·104
72	10	1·29	27	3·333
72	9	1·56	27	3·333
72	8	2·24	28	3·214
72	7	2·51	27	3·333
72	6	3·18	27	3·333
72	5	3·45	27	3·333
72	4	4·11	26	3·461
72	3	4·40	29	3·104
72	2	5·8	28	3·214
72	1	5·37	29	3·104

EXPERIMENT III.

Load 21½ tons, which added to 6½ tons, the weight of the barge gives 28 tons; fraction of force to whole effect $\frac{1}{203}$.

Tractive force employed.	No. of Stakes.	Time.	Time between the Stakes.	Velocity per hour in miles.
308 lbs.	1	0·38″	38″	2·395
308	2	1·3	25	3·600
308	3	1·26½	23½	3·829
308	4	1·49½	23	3·918
308	5	2·12	22½	4·000
308	6	2·34½	22½	4·000
308	7	2·57½	23½	3·829
308	8	3·21	23½	3·829
308	9	3·44½	23½	3·829
308	10	4·9	24½	3·673
308	11	4·32	23	3·918
308	12	4·56	24	3·750
308	13	5·19	23	3·918

EXPERIMENT IV.

Load as above; fraction of force to whole effect $\frac{1}{814}$.

Tractive force employed.	No. of Stakes.	Time.	Time between the Stakes.	Velocity per hour in miles.
77 lbs.	1	1·6″	1·6″	1·363
77	2	1·54	48	1·875
77	3	2·34½	40	2·222
77	4	3·13	38½	2·337
77	5	3·49	36	2·500
77	6	4·25½	36	2·500
77	7	5·1	36	2·500
77	8	5·37½	36½	2·465
77	9	6·15	37½	2·400
77	10	6·42½	37½	2·400
77	11	7·30	37½	2·400
77	12	8·6	36	2·500
77	13	8·42	36	2·500

APPENDIX D.

The following, of which an extract taken from the Courier of April the 29th, forms a part, is communicated by a friend.

CANAL NAVIGATION.

(*From a Correspondent.*)

"An experiment was made a few days ago on the Paddington Canal, for the purpose of ascertaining the practicability of moving a boat, with passengers, at quick velocity. A boat constructed of *cast* iron, of the lightest and most favourable build for rapid passage, was used on the occasion. About thirty-eight gentlemen, many of them engineers, were passengers. It has been asserted, that at the velocity of seven or eight miles an hour, the surge or wave, commonly observed at three or four miles an hour, becomes hardly perceptible. This, however, was proved to be not the fact by this experiment. The boat was drawn by two horses, and, when running at nine miles and a half an hour, (the maximum speed,) was followed by a wave of sometimes seventeen inches, sometimes a foot, and, on an average, nine inches, washing the banks with great force, and very often completely covering the towing path, displacing the gravel just as the tide on a shore. The distance run was three miles, at the end of which the poor horses had not a dry hair left; the result shows that nine miles an hour was too great a speed to attempt if the horses or the canal banks are to be at all regarded."

It may be, perhaps, easy to account for the observations with which it concludes, by stating, that many gentlemen, interested in railways, as proprietors or engineers, were of the party; the fact, that the boat went for three miles at the rate of nine miles per hour, with thirty-eight passengers, is fully acknowledged by the person who inserted the paragraph; the reported disadvantages, as to the banks of the canal suffering from that speed, are answered in page 33. We may form some judgment of the accuracy of the reporter, from his statement, that the boat was constructed of *cast* iron; and of the degree of his candour, from the eagerness with which he seizes the circumstance of the two almost untrained and eager horses being heated by the three miles journey, to infer the incapacity of trained horses performing the required work; when there existed indubitable testimony, of which he could not be ignorant, as to what has been done, in the last year, on the Glasgow and Paisley Canal, viz. "That the entire number of horses kept in the year 1832, to work the improved boats *one hundred* and *fifty-two miles* each day, was twenty-eight, including the spare ones;" and that establishment gave a power to carry upwards of one thousand passengers per day, as is shown by the fact, that there were carried along the twelve miles of this canal nearly *two thousand five hundred passengers* in two days, viz. 31st of December, 1832, and 1st of January, 1833.

F. P.

APPENDIX E.

The following is the result of the Experiment made on the Oxford Canal, communicated by W. Cubitt, Esq., July 4, 1833, *Barby Fields.*

FIRST EXPERIMENT.				SECOND EXPERIMENT.			
Hour.	Min.	Sec.	Seconds per furlongs.	Hour.	Min.	Sec.	Seconds per furlong.
Start 9	2	25		Start 9	28	27	
,,	2	55	28	,,	29	27	40
,,	3	32	37	,,	29	46	39
,,	4	8	36	,,	30	26	40
,,	4	47	37	,,	31	4	38
,,	5	37	40	,,	31	45	41
,,	6	4	27	,,	32	24	31
,,	6	45	41	,,	33	4	40
,,	7	24	39	,,	33	46	42
,,	—	—	—	,,	34	27	41
,,	—	—	—	,,	35	9	42
,,	9	22	—	,,	35	50	41
,,	10	2	—	,,	36	35	45
1½ Miles in 7 Min. 35 Sec.				1½ Miles in 8 Min. 8 Sec.			

	Min.	Sec.
First experiment	7	35
Second experiment	8	8
3 Miles in	15	43

Equal to 12 Miles in 1 hour, 2 minutes, and 52 seconds.

APPENDIX F.

The following extracts from letters recently received show the progress that has been made in conveying passengers in light boats on different canals.

Letter No. I. shows the increase of passengers on the Paisley boats, in the first five months of the year 1833; in the last two months of that year, to wit, April and May last, an additional trip to Johnstone has been done, which increases the number of miles run per day to 176.

Letter No. II. shows the last accounts of the Lancaster Canal boats, which commenced to ply in April last.

Letter No. III. gives the account of the progress of the quick boats, which commenced to ply on the Forth and Clyde Canal in April, 1833. In the year 1832, steam and horse power on the old system were employed: the time taken to do about twenty-five miles, including the passing of four locks and eleven drawbridges, was, by steam four hours, and by horses five hours and a half; the time is now reduced to about three hours and a quarter. At the end of 1832, the canal companies between Edinburgh and Glasgow threw open to the public the passenger trade during the night, and there are now three boats which pass each way, carrying goods and passengers run by the companies, trading between those towns.

The number of opportunities on the Forth and Clyde Canal was, in 1832, three each way per day. In 1833, the opportunities are six, to wit, three during the day given by the company, and three during the night run by the traders; but it will be seen, from the return, that the three new opportunities during the night have not hurt the canal companies' day passage-boat revenue, which has increased twenty-five per cent. in the year 1833. The terms on which the night passage-boats are run, are one-fourth of the gross fares between Edinburgh and Glasgow to each of the two Canal Companies, the traders retaining a half to themselves. The charges are, five shillings and three and sixpence for the entire distance of fifty-seven miles, and proportionately for intermediate distances.

LETTER I.

DEAR SIR,

I have yours of yesterday's date, enquiring the number of passengers by our boats for the last five months, &c. &c.; in answer, we had in

January	12,126
February	14,350
March	17,438
April	21,597
May	25,955
	91,466

The only stoppage we had last winter was in January for four days, from 23rd to 27th inclusive, and before giving it up the ice was in general one inch and a half to two inches thick, and many large pieces double that thickness, from one being shoved on the top of another, and frozen together.

We find no difficulty in going through new formed ice of one inch thickness.

Thomas Graham, Esq.

LETTER II.

Lancaster, 29th June, 1833.

DEAR SIR,

In reply to your favour of the 27th, I beg to state that our swift boat leaves Preston every Morning, except Tuesday, at half-after nine, and will continue to do so until Tuesday, 9th July, on which day, and afterwards, she will leave Preston at half-after one o'clock.

Our boat has been going on uncommonly well in every respect, the number of passengers steadily improving. On the 9th July, the boat will sail from Kendal to Preston, and back to Kendal, daily, and coaches from Manchester and Liverpool will meet the boat at Preston. The distance to perform daily will be one hundred and fourteen miles, (including eight locks and a tunnel,) which we propose to do in seven hours each way of fifty-seven miles.

Thomas Graham, Esq.

LETTER III.

Canal Office, Glasgow, 29th June, 1833.

DEAR SIR,

The passengers are increasing to and from every direction, which you will see from the following note of the collections for the last five days, as compared with the same days of last year.

	1832.			1833.		
Monday	£18	15	0	£30	17	1
Tuesday	23	15	0	26	6	1
Wednesday	17	13	0	33	2	7
Thursday	18	14	0	24	15	0
Friday	22	6	0	28	16	4
	£101	3	0	£143	17	1
				101	3	0
				42	14	1
Off paid by night boats				17	13	1
Increase of day boats in five days				£25	1	0

The Union Canal Company have now got the other boat, and we shall have two conveyances each day to and from Edinburgh, which will increase the passengers still more. The conveyance to Edinburgh is not yet advertised, but will be so on Monday. The Stirling coach to the Canal is doing remarkably well and will increase. I hope that the coach run between Stirling and Glasgow will soon give up. The fares have been reduced by the proprietors, but I hear, without any increase of the passengers. This cannot continue long. I am turning my attention to have a conveyance from Alloa to Dumfermline: this I hope to accomplish next week.

Thomas Graham, Esq.

NOTE OF A SERIES OF EXPERIMENTS,

Made on the Forth and Clyde Canal, with Mr. Grahame's Twin Boat, Swift, on Friday, the 9th of July, 1830.

Temperature 59°

No. of Experiments.	Weight of boat and cargo.			Draught of water, in inches.			No. of horses.	Miles on canal.	TIME.		Miles per hour.	Force of traction in lbs.	Average width of canal.		Average depth of canal.		REMARKS.
	cwt.	qrs.	lbs.	Bow.	Stern.	Mean.			Min.	Sec.			Ft.	In.	Ft.	In.	
1	116	1	14	14½	16½	15½	2	1	14	28	4.14	54.40	63	,,	9	9	Against the wind, light breeze.
2	,,	,,	,,	,,	,,	,,	,,	,,	14	15	4.21	34.00	,,	,,	,,	,,	With the wind.
3	,,	,,	,,	,,	,,	,,	,,	,,	9	45	6.15	128.70	,,	,,	,,	,,	Against the wind, a ripple was observed rising at the bows, and extending to the banks on each side of the canal.
4	,,	,,	,,	,,	,,	,,	,,	,,	9	35	6.26	93.80	,,	,,	,,	,,	With the wind, ripple the same.
5	,,	,,	,,	,,	,,	,,	,,	,,	8	,,	7.50	207.50	,,	,,	,,	,,	Against the wind, with a slight surge at stern.
6	,,	,,	,,	15½	16½	16	,,	,,	7	50	7.65	202.35	,,	,,	,,	,,	With the wind, surge the same.
7	,,	,,	,,	16	16	16	,,	,,	7	29	8.01	264.30	,,	,,	,,	,,	Against the wind, the surge a little increased.
8	,,	,,	,,	,,	,,	,,	,,	,,	6	28	9.27	272.20	,,	,,	,,	,,	With the wind, surge the same.
9	,,	,,	,,	14½	15½	15	,,	,,	7	22	8.14	266.50	,,	,,	,,	,,	No sensible difference in surge.
10	,,	,,	,,	,,	,,	,,	,,	,,	7	35	7.91	243.20	,,	,,	,,	,,	Wind nearly subsided—surge the same.
11	,,	,,	,,	,,	,,	,,	,,	,,	7	6	8.45	328.00	,,	,,	,,	,,	Rather more surge at stern.
12	,,	,,	,,	,,	,,	,,	,,	,,	7	17	8.23	298.00	,,	,,	,,	,,	,, ,, ,, ,, ,,
13*	,,	,,	,,	,,	,,	,,	4	,,	4	52	12.32	410 lbs.	,,	,,	,,	,,	Surge decreased.
14	61	2	7	7	9	8	4	,,	4	16	14.06	352· 6	,,	,,	,,	,,	In this experiment the surge was greatly diminished—a rippling wave only seen at the stern, and not the least surge in front of the boat.

* The mercury stood fixed in this experiment at 410 lbs.

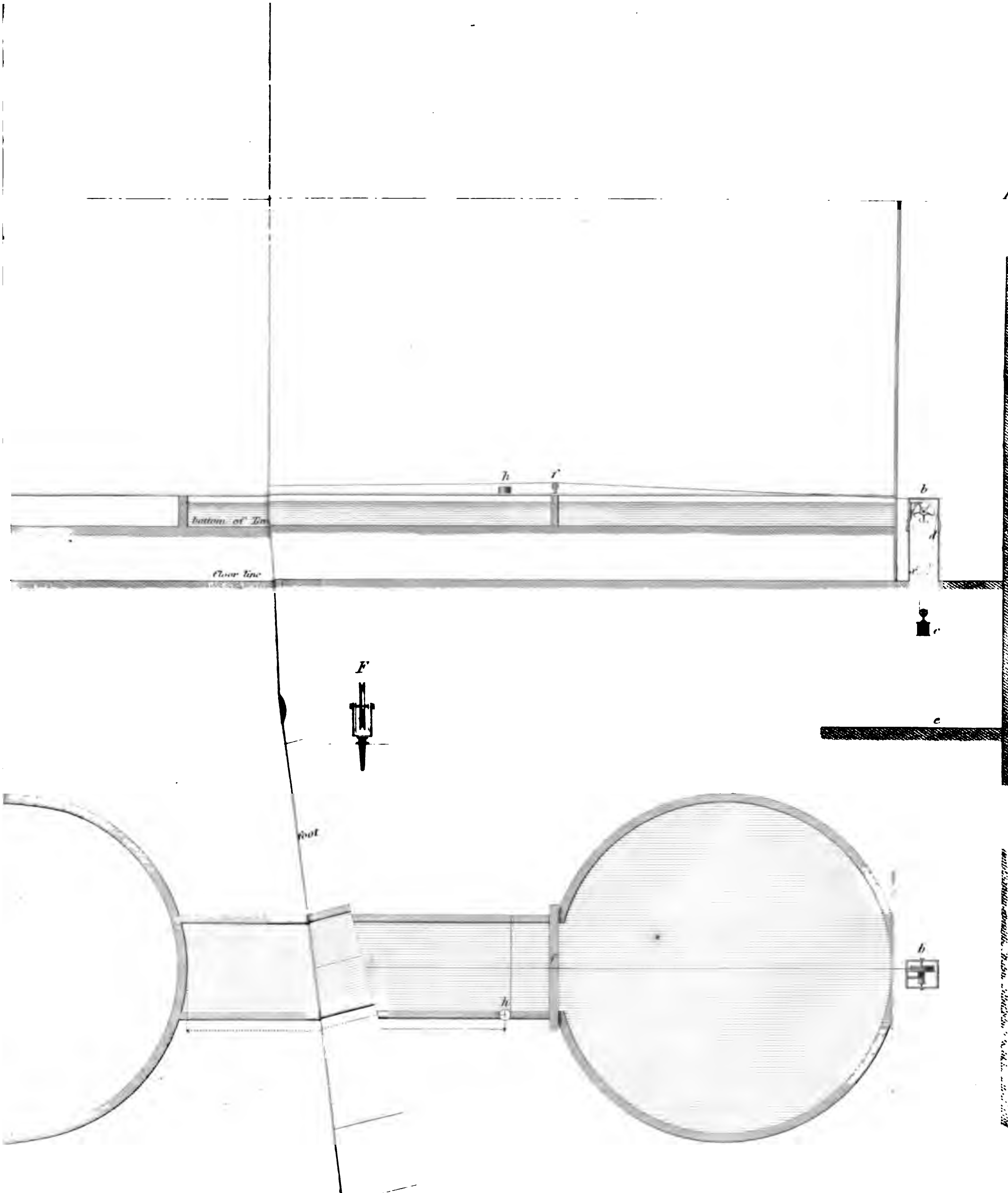
NOTE OF EXPERIMENTS,

Made with the Twin Boat on the Monkland Canal, on the 12th of July, 1830.

No. of Experiments.	Weight of boat and cargo.			Draught of water, in inches.			No. of horses.	Miles on canal.	TIME.		Miles per hour.	Force of traction.	Average width of canal.		Average depth of canal.		REMARKS.
	cwt.	qrs.	lbs.	Bow.	Stern.	Mean.			Min.	Sec.		lbs.	Ft.	In	Ft.	In.	
1	108	2	24	14½	16	15¼	3	¼	3	5	4.86	72.0	40	,,	5	4	With the wind, and no surge.
2	,,	,,	,,	,,	,,	,,	3	¼	3	7	4.81	92.0	,,	,,	,,	,,	Against the wind no surge.
3	,,	,,	,,	,,	,,	,,	3	¼	2	23	6.29	191.3	,,	,,	,,	,,	With the wind, a slight surge.
4	,,	,,	,,	,,	,,	,,	3	¼	2	26	6.16	219.3	,,	,,	,,	,,	Rather more wind a-head, with a slight surge at stern.
5	,,	,,	,,	,,	,,	,,	3	¼	2	11	6.87	389.0	,,	,,	,,	,,	With the wind, same swell.
6	,,	,,	,,	,,	,,	,,	3	¼	1	57	7.69	368.1	,,	,,	,,	,,	Against the wind, a swell in front and stern, rolling over the banks of the canal.
7	,,	,,	,,	,,	,,	,,	3	¼	1	21	11.11	420.0	,,	,,	,,	,,	With the wind, no surge.
8	,,	,,	,,	,,	,,	,,	3	¼	1	14	12.16	446.9	,,	,,	,,	,,	No surge—wind subsided.
9	,,	,,	,,	,,	,,	,,	3	¼	1	12	12.50	439.3	,,	,,	,,	,,	No wind, and no surge.
10	57	,,	9	The draught not measured.			3	¼	1	9	13.04	390.0	,,	,,	,,	,,	Light breeze a-head, no surge: a part of the cargo removed from the boat.

LONDON:
ROAKE AND VARTY, PRINTERS, 31, STRAND.

Plat



...awn by G. Turnbull.

Engraved by E. Tur...

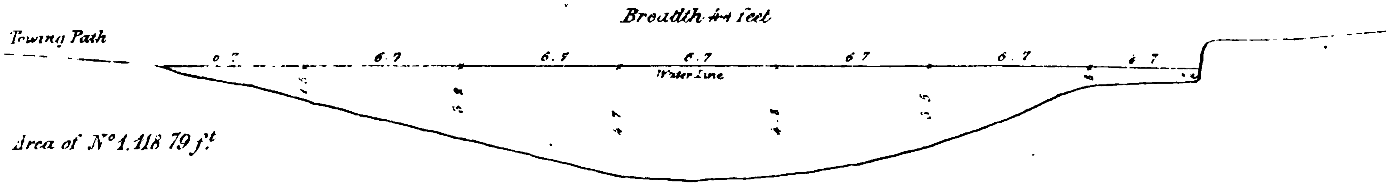
Paddington Canal.

Transverse Sections. — 100 Yards apart – taken 1st April 1833.

by Mr Bourns and Mr Turnbull.

Section N° 1. – near Bridge N° 6

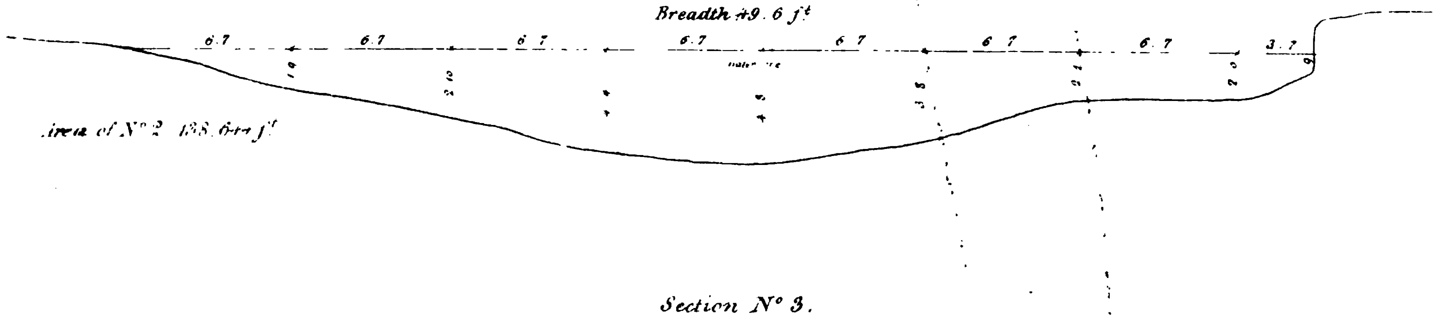
Breadth 44 feet



Area of N° 1. 118.79 f^t

Section N° 2. – 100 yds West of the above

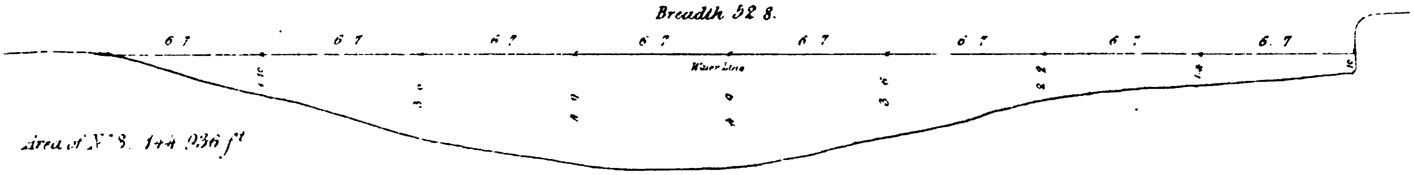
Breadth 49.6 f^t



Area of N° 2. 138.644 f^t

Section N° 3.

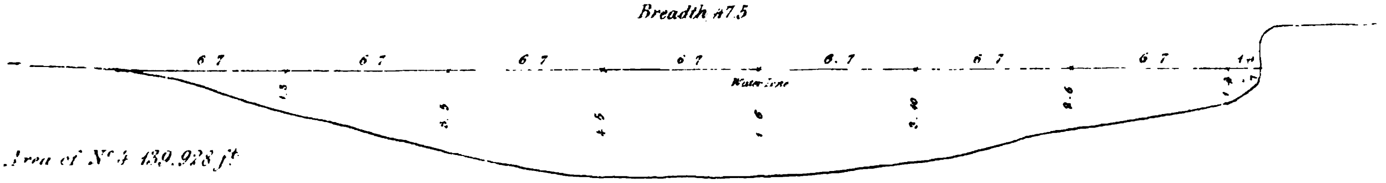
Breadth 52.8.



Area of N° 3. 144.936 f^t

Section N° 4.

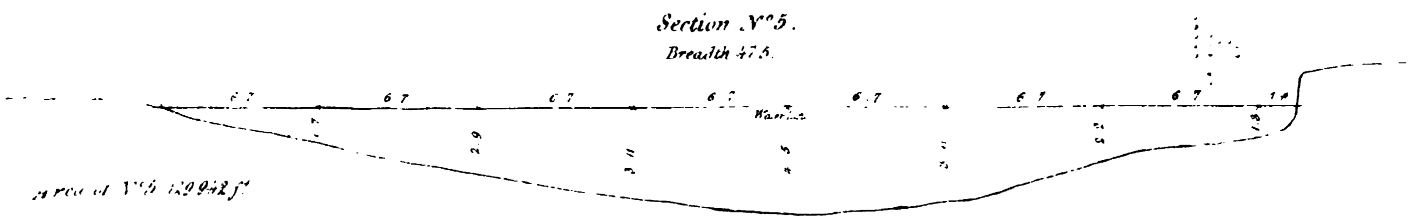
Breadth 47.5



Area of N° 4. 130.928 f^t

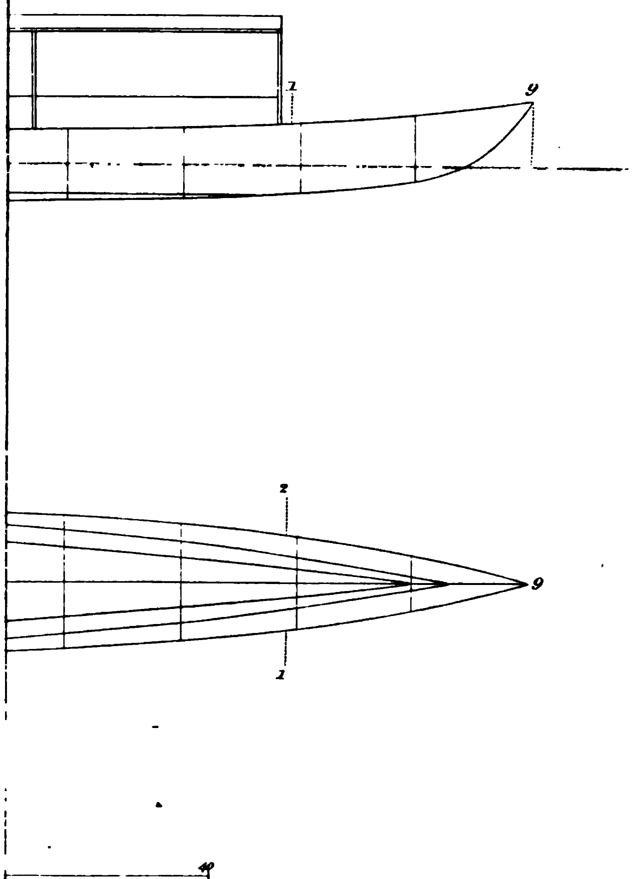
Section N° 5.

Breadth 47.5.



Area of N° 5. 129.942 f^t

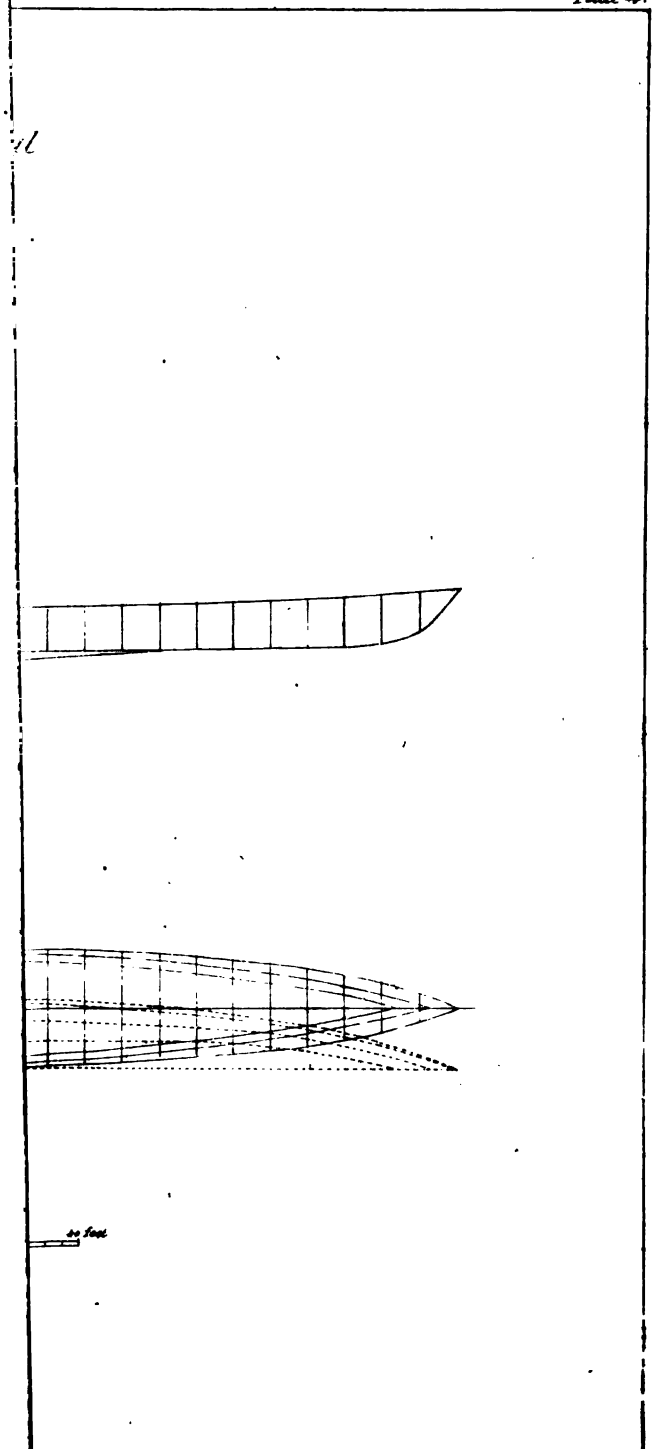
PLATE III.



Drawn by G. Turn[illegible]

Engraved by E. Turrell.

Plate 4.



th and Clyde Canal.

		Tons	Cwt
Buoyancy	6 inches	1	7
do	12	6	0
do	18	11	11